STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION

NATURAL HISTORY SURVEY DIVISION
STEPHEN A. FORBES, *Chief*

BULLETIN

OF THE

Illinois State Natural History Survey

URBANA, ILLINOIS, U. S. A.

VOLUME XIII
1918—1921

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

1922

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SCHNEPP & BARNES, PRINTERS
SPRINGFIELD, ILL.
1922

62355—600

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ERRATA

Page 97, line 17, for first *larval* read *pupal.*
Page 112, in legend, for *jonessi* read *jonesii.*
Page 114, in legend, for *or* read *of.*
Page 125, line 4, for *Bonosa* read *Bonasa.*
Page 131, in legend, for *hirundinaceus* read *hirudinaceus.*
Page 138, last line, for *coccoon* read *cocoon.*
Plate XII, explanation page, next to last line, for *acrivora* read *aerivora.*
Plate XIII, explanation page, next to last line, for *White-grubs* read *White-grub.*
Page 293, Figure 5*a* was reversed in printing, and the two items of the legend should change places.
Page 515, second table, for *Pelocoris femorata* read *Pelocoris femoratus.*

ARTICLE I.—*The North American Species of the Genus Tiphia (Hymenoptera, Aculeata) in the Collection of the Illinois State Natural History Survey.* BY J. R. MALLOCH.

INTRODUCTION

In the course of the work upon white-grubs (Phyllophaga spp.) by various members of the staff of the Illinois State Entomologist's office many specimens of the parasitic hymenopterous genus Tiphia have been obtained either by rearing from the larvae or pupae or in general collections of imagines. About two years ago I undertook to work up this mass of material with a view to determining how many species there are affecting white-grubs in Illinois, and also to determine, in so far as our material permits, the distribution of the various species. At the outset of my work I encountered great difficulties to progress, chief of which was the extremely unsatisfactory nature of the descriptions of most of the previously described forms. Coupled with this is the fact that the species are remarkably closely related, presenting but few characters that are appreciable except after considerable study. After several months of intermittent study of our material, I was forced to the conclusion that it was necessary for me to obtain specimens from more diverse localities in order to enable me to determine satisfactorily whether certain trivial characters possessed a specific significance; consequently on every possible occasion during my field work in 1917, I collected specimens of Tiphia, and I also borrowed a large number of specimens from Mr. Nathan Banks, the latter containing examples from many states in the Union.

I endeavored by dissection of the males to use the structure of the hypopygium as a check upon my separation of specimens by external characters such as punctuation, venation, and the shape of various parts of the body; but the hypopygia of closely related species, or at least of forms that appeared to me to be such, resemble each other so closely that I found very little assistance could be obtained from a study of these.

I also arrived at the decision that the punctuation of the various parts of the body, while fairly constant and very useful for specific separation, is subject to variation, small specimens of such species as *inornata* Say usually being almost devoid of the minute interspersed punctures which are characteristic of normal-sized specimens. These small specimens are probably the result of starving in the larval stage—a condition frequently found in predaceous and parasitic forms.

One of the most important characters that I discovered in the genus is a longitudinal groove on the inner or posterior surface of the basal joint of the hind tarsi of the females in the section to which *punctata*

Robertson belongs. This groove is absent in the females of *inornata* Say and its close allies and also in the males of all species that I have examined, so that it can not be used as a subgeneric character, more especially as the males of the two groups are not separable from the *punctata* group, as far as I can discover, by any character or set of characters that is found in all of these species. What the function of this groove is I can not determine; it may not have any particular function, but the apical spur on the posterior side of the hind tibia is so placed that it can fit into the groove and may form, or have formed at one time in the evolution of the group, a stridulatory organ. Stridulatory organs in the Hymenoptera are normally found on the thorax and abdomen, and in other groups on the wings, abdomen, thorax, and legs. That the tarsal groove above mentioned may have some function altogether different from the one suggested here is quite possible.

The peculiar curved horn-like process at the apex of the abdomen in the males of Tiphiinae is the eighth ventral abdominal segment and not part of the hypopygium.

The females of at least the larger species can sting a person's hands, as I know from experience, but I have handled dozens of females of the smaller species without being stung by them.

In collecting specimens during 1917 particular attention was paid to localities in which no previous effort had been made to obtain a representative series of this group, with the result that considerable numbers of species were found that were not previously represented in our collection. At Dubois, in the southern part of the state, many examples of several small species were taken by sweeping black-jack oak; and later in the year some of the same species were found under the same conditions at Havana and at Meredosia.

It is not to be assumed that the Tiphia species discussed in this paper constitute an exhaustive list of those occurring in Illinois, and it is certain that a very large number of those occurring in the United States are unknown to me; but the present paper contains the most comprehensive survey of the North American species yet attempted, contains many new characters for the differentiation of the species, and should prove useful to students of the group.

Habits of Species

So far as is known the larvae of Tiphiae are ectoparasitic upon coleopterous larvae. The habits of several species described in this article are discussed in another article in this volume, by Mr. J. J. Davis.

The species particularly affecting white-grubs in cultivated lands are absent from the sand regions near Havana and Meredosia, Illinois, the common species in these localities being much smaller than those that attack white-grubs. They probably feed upon larvae of Scarabaeidae occurring in the groves of black-jack oak, which are characteristic of these regions. It is noteworthy that at Dubois I found some of the small

Tiphiae that occur so commonly at Havana, and that many species of Hemiptera, Orthoptera, and Coleoptera which are peculiar to sand regions occur also at Dubois though the soil is much heavier than at Havana and at similar localities.

Very few imagines were taken on flowers in the sand regions, though I swept Chrysopsis, Monarda, and several less common plants. The flowers of wild parsnip and Angelica yielded many examples of the species affecting white-grubs at Galena and other northern points in 1917, and there are many records of similar habits in our office files relating to these species.

Generic Characters

The genus Tiphia has been separated by authors from Paratiphia by the absence of the first cubital cross-vein of the wing, and the slightly convergent sides of the metathoracic enclosure. These characters, while fairly constant, are not altogether reliable, as many specimens of Tiphia have the first cubital present and the metathoracic enclosure is always narrowed posteriorly, though not subtriangular in shape. There are a number of species in Tiphia that have the first dorsal abdominal segment similar to that of Paratiphia—with a deep transverse linear groove at middle—so that in so far as the absence or presence of the groove is concerned it is impossible to separate the genera by the structure of this segment. There is, however, on each side of the first segment in Paratiphia a conspicuous oval depression which is but slightly indicated in Tiphia. The principal distinctions between Tiphia, Paratiphia, and the new genus Neotiphia may be summarized as follows:—

Male with clypeus usually entirely or in large part white; first cubital transverse nervure always present; mouth-opening much longer than broad, extending almost to back of head, the portion between the latter and posterior margin of mouth vertical; metathoracic enclosure subtriangular; first dorsal abdominal segment abrubtly declivitous anteriorly, with a deep transverse incision at middle, and a very distinct oval depression on each side; male hypopygium as in Figures 1, 2, and 3.....*Paratiphia.*

Male with clypeus black; first cubital transverse nervure normally absent; mouth-opening much longer than broad, extending almost to back of head, the portion between it and back of head horizontal; metathoracic enclosure narrowed posteriorly but not subtriangular; first dorsal abdominal segment not abruptly declivitous anteriorly, without an oval depression on each side; male hypopygium as in Figures 4 and 6.....*Neotiphia.*

Male with clypeus black; first cubital transverse nervure normally absent; mouth-opening broader than long, separated from back of head by a rather broad flat area; metathoracic enclosure slightly narrowed posteriorly; first abdominal segment not abruptly declivitous anteriorly, without well-defined oval depression on each side; male hypopygium as in Figures 5, 7, and 8.....*Tiphia.*

Key to Species known to Author

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— Sixth ventral abdominal segment without a central groove 3

2. Lower central portion of clypeus broadly rounded at apex; oral opening extending caudad little more than half-way to posterior margin of head from base of mandible ..... *canaliculatus*, sp. n.
— Lower central portion of clypeus acutely pointed; oral opening extending almost to back of head; mandibular triangle absent ..... *(Neotiphia) acuta*, sp. n.

3. Ventral abdominal segments 3 to 5 each with a sharp tooth on middle of disc on each side ..... *odontogaster* Viereck.
— At most the fifth ventral segment with such tooth, or with an elongate transverse ridge on each side of disc 4
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4. Mesopleurae doubly punctate on the entire surface; clypeus with lower central portion transverse at apex, punctate almost to margin; fore tibiae in front and flagellum below ferruginous 5
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— Mesopleurae with large and small interspersed punctures on the entire surface 14

11. Angulation of radius less than one-fifth the distance from stigma to transverse vein; lateral dorsal areas of metathorax coarsely rugose-reticulate .....*rugulosa*, sp. n.

— Angulation of radius at least one-third the distance from stigma to transverse vein; lateral dorsal areas of metathorax not rugose-reticulate except posteriorly 12

12. Apex of third cubital cell much distad of apex of marginal; occiput densely punctate, so that there are behind eyes no glossy spaces between the punctures; basal dorsal abdominal segment with a broad shallow post-marginal depression.....*occidentata*, sp. n.

— Apex of third cubital cell not appreciably beyond apex of marginal; occiput glossy, punctures behind eyes separated; basal dorsal abdominal segment with a deep linear post-marginal depression.....13

13. Third cubital cell ending almost in line with apex of marginal.*similis*, sp. n.

— Third cubital ending very distinctly proximad of apex of marginal.....21

14. Clypeus slightly convex on disc, center of apical margin slightly emarginate, the edge rounded, without any flat depressed rim, punctate to apex..... .....*clypeolata*, sp. n.

— Clypeus not as above, there being usually a distinct impunctate flat margin at apex or the central emargination not being regularly rounded.....15

15. Apex of marginal cell not extending distad of apex of third cubital, or very slightly so (Fig. 13).....16

— Apex of marginal cell extending very conspicuously beyond apex of third cubital (Fig. 12).....21

16. Dorsum of prothorax with minute punctures interspersed between the large punctures on disc; clypeus flat.....17

— Dorsum of prothorax without the minute interspersed punctures except on margins; clypeus usually convex.....18

17. Sixth ventral abdominal segment with very long yellowish upright hairs on the greater portion of disc.....*inornata* Say.

— Sixth ventral abdominal segment with short whitish decumbent hairs on greater portion of disc.....*vulgaris* Robertson.

18. Basal dorsal abdominal segment with shallow poorly defined post-marginal depression 19

— Basal dorsal abdominal segment with deep linear post-marginal depression 20

19. Sixth ventral abdominal segment with long yellowish erect hairs on greater portion of disc.....*inornata* Say.

— Sixth ventral abdominal segment with short whitish decumbent hairs on greater portion of disc..... .....*vulgaris* Robertson.

20. Mesopleurae with small, widely separated punctures and minute interspersed punctures on a glossy surface; tegulae with an incised line around outer and posterior margins.....*winnemanae*, sp. n.

— Mesopleurae with large and small interspersed punctures on disc, the former on at least the anterior half not separated by more than the width of one of the large punctures; tegulae without complete incised marginal line .....*punctata* Robertson.

21. Abdominal segments 2 to 5 each with a slender incised line along posterior margin; incision between first and second dorsal abdominal segments very deep owing to the front margin of the latter being abruptly declivitous .....*affinis*, sp. n.

— Abdominal segments 2 to 5 without incised line on posterior margin, or if it is present it is very broadly interrupted at middle; incision between first and second dorsal abdominal segments normal, the front margin of second segment not abruptly declivitous.....22

22. Basal dorsal abdominal segment with a deep narrow post-marginal incision; antennae usually black.....*inaequalis*, sp. n.

— Basal dorsal abdominal segment with a broad, shallow, punctate depression near posterior margin; antennae usually conspicuously ferruginous on under surface of flagellum.....23

23. Basal dorsal abdominal segment with a large part of center of the declivitous anterior portion with minute closely placed punctures.....*conformis*, sp. n.

— Basal dorsal abdominal segment with large irregularly arranged punctures on entire surface of the declivitous anterior portion.....*egregia* Viereck?

24. Legs entirely black; first dorsal abdominal segment sometimes with a tubercle near posterior margin.....*floridana* Robertson.

— Legs more or less yellowish, especially the fore tibae and the tarsi; first dorsal abdominal segment without a tubercle.....*illinoensis* Robertson.

FEMALES

1. Pygidium punctate to apex.....2

— Pygidium with a large portion of surface before apex impunctate.....3

2. Oral opening very narrow, extending almost to back of head, post-mandibular triangle absent .....*(Neotiphia) acuta*, sp. n.? *

— Oral opening broad, not extending almost to back of head, post-mandibular triangle distinct .....*floridana* Robertson.

3. Tegulae much longer than broad, very distinctly shagreened.....*transversa* Say.

— Tegulae as broad as long, usually glossy and not shagreened.....4

4. Basal joint of hind tarsi without a distinct groove on the posterior surface 5

— Basal joint of hind tarsi with a distinct longitudinal groove on posterior surface (Fig. 9) 7

5. Punctures on pygidium extending to a short distance from apex; ventral surface of pronotum doubly punctate on entire surface.....*vulgaris* Robertson.

* See notes on *Tiphia luteipennis* following description of *acuta*.

— Punctures on pygidium ceasing at, or slightly beyond, middle of exposed surface; ventral surface of pronotum doubly punctate only on margins..6

6. Declivitous portion of basal dorsal abdominal segment doubly punctate on its entire surface, the minute punctures very closely placed, the large ones widely placed.....*inornata* Say.

— Declivitous portion of basal dorsal abdominal segment with large irregularly placed punctures, the small closely placed punctures absent..... .....*clypeata* Robertson.

7. Clypeus punctate almost to apical margin, the apex with a round almost abruptly declivitous emargination.....*clypeolata*, sp. n.

— Clypeus usually impunctate on a narrow space along apical margin, the apical emargination when present not abruptly declivitous.....8

8. Pygidium with very distinct shagreening almost to apex; basal dorsal abdominal segment with a very shallow post-marginal depression in which are 2–3 series of punctures.....9

— Pygidium without distinct shagreening, or if this is present it does not extend almost to apex, or the basal dorsal abdominal segment has a deep linear post-marginal incision in which there is but one series of punctures 10

9. Basal angulation of radius about one-sixth of the distance from stigma to first complete transverse nervure; clypeus with 1–2 transverse series of punctures on middle.....*rugulosa*, sp. n.

— Basal angulation of radius about one-third of the distance from stigma to first complete transverse cubital nervure.....*odontogaster* Viereck.

10. Mesopleurae with very distinct though microscopic shagreening on surface, which gives it a subopaque appearance; sides of metathorax with very coarse shagreening even on the upper rugose portion; basal dorsal abdominal segment with broad shallow post-marginal depression..... .....*tuberculata*, sp. n.

— Mesopleurae glossy on disc, without shagreening, or species not as above in other respects 11

11. Basal dorsal abdominal segment with a deep transverse median incision; clypeus punctate almost to apex.....*incisurata*, sp. n.

— Basal dorsal abdominal segment without transverse incision.....12

12. Tegulae with a deep impressed line round their outer and posterior margins; basal dorsal abdominal segment with a shallow broad post-marginal depression 13

— Tegulae either without an impressed marginal line or, if this is present, it does not encircle the entire outer and posterior sides.....15

13. Face not distinctly buccate in center above antennae; viewed from above its anterior margin is almost transverse, punctures very sparse, those on lower portion not closely placed; space between posterior margin of oral opening and back of head very broad, greater than one-third the length of head .....*tegulina*, sp. n.

— Face distinctly buccate above antennae; punctures on lower half of face contiguous; space between posterior margin of oral opening and back of head very narrow, about one-fourth as great as length of head.....14

14. Large species, 12 mm. in length.....*conformis*, sp. n.

— Smaller species, 8 mm. in length.....*imitatrix*, sp. n.

15. A large portion of center of basal dorsal abdominal segment with minute closely placed punctures which extend caudad almost to post-marginal depression .....*arida*, sp. n.

— If there are any small closely placed punctures present on basal dorsal abdominal segment they are confined to declivitous anterior portion and do not extend caudad on dorsum.....16

16. Lower half of sides of metathorax conspicuously though finely shagreened or cross-striated, the minute setiferous punctures indistinct.....17

— Lower half of sides of metathorax very faintly and indistinctly shagreened or striated, appearing glossy, the minute setiferous punctures distinct..18

17. Large species, averaging 11 mm. in length, post-mandibular triangle smooth and glossy; basal dorsal abdominal segment with broad poorly defined post-marginal depression .....*robertsoni*, sp. n.

— Smaller species, averaging 8–9 mm. in length; post-mandibular triangle distinctly shagreened; basal dorsal abdominal segment with narrow well-defined post-marginal depression which is sometimes interrupted ventrally ..... { *affinis*, sp. n. / *inaequalis*, sp. n. }

18. Anterior declivitous portion of basal dorsal abdominal segment with double punctuation on its entire surface.....*aterrima*, sp. n.

— Anterior declivitous portion of basal dorsal abdominal segment with irregular single punctuation or doubly punctate in center.....19

19. Ventral surface of prothorax with double punctuation on disc; entire ventral surface of thorax and coxae with very distinct microscopic shagreening which prevents them from having a glossy appearance; greater portion of pygidium indistinctly shagreened.....*reticulata*, sp. n.

— Ventral surface of thorax not as above, at least the flap-like posterior extensions of mesothorax highly glossy.....20

20. Pygidium distinctly shagreened on apical half.....21

— Pygidium not distinctly shagreened on apical half.....22

21. Pygidium very distinctly shagreened on apical half; dorsal abdominal segments 2 and 3 usually without a trace of an incised line along the posterior margins (cf. *texensis*).....*punctata* var. *intermedia*, var. n.

— Pygidium indistinctly shagreened on apical half; abdominal segments 2 and 3 in *robertsoni* and *affinis* with a distinct incised line along their posterior margins 22

22. Lower half of sides of metathorax with very distinct though microscopic shagreening; apical half of pygidium glossy.....(see 16)

— Lower half of sides of metathorax with very faint shagreening; apical half of pygidium with more or less shagreening at its base.....23

23. Large species, over 15 mm. in length; dorsal abdominal segments 2 and 3 without incised line along posterior margin.....*texensis*, sp. n.
— Smaller species, not over 14 mm. in length; dorsal abdominal segments 2 and 3 without an incised line along their posterior margins.....*punctata* Robertson.

Description of Species

Neotiphia, gen. nov.

This genus is separable from Tiphia by the much longer and narrower oral opening which extends to, or almost to, the back of the head; the glossy post-mandibular triangle so conspicuous in Tiphia is absent or linear, and the palpi are very much shorter than in that genus. The clypeus is black, and in the genotype male it is pointed below, while in the female it is narrowly produced centrally, with the apical outline of the produced part rounded. The abdomen resembles that of Paratiphia at base, though not so abruptly declivitous on anterior portion of first dorsal segment. The hind metatarsi of female have the groove on posterior surface long and deep. The venation is similar to that of Tiphia.

Genotype, *Neotiphia acuta*, sp. n.

Neotiphia acuta, sp. n.

Male.—Black, glossy; palpi yellowish; tarsi brown; wings yellowish brown except at apices; veins and stigma black-brown; hairs white.

Face doubly punctate above antennae, on other portions with large and rather widely spaced punctures; clypeus subtriangular, terminating in an acute point below, surface with dense, minute punctures, and larger punctures below; antennae submoniliform below; mandibles simple; palpi much shorter than in Tiphia, apical joint of maxillary palpus not over four times as long as its greatest diameter; oral opening narrow, its length more than 1.5 its posterior width, nearly parallel-sided, extending nearly to posterior margin of head; post-mandibular triangle absent; cheeks with sparse large punctures. Pronotum with large deep punctures; mesopleura with large, deep subcontiguous punctures. Metathoracic enclosure narrowed posteriorly, posterior face of metathorax slightly rugose below, doubly punctate on greater portion of surface. Basal dorsal abdominal segment with an incised line at middle, which is distinctly angulate centrally; punctures on disc of segment large, no impressed apical line present; remaining segments, except apical, with large shallow punctures which are closer near anterior and posterior margins, forming usually a single transverse line; segments 1–5 each with a broad impunctate apical margin; sixth segment with large, deep, contiguous punctures; ventral segments similar to those of dorsum, the basal segment flattened as usual, and the sixth with much smaller punctures and a very conspicuous broad shallow channel in

center on apical half. Venation resembling that of *Tiphia inornata,* the vein closing marginal cell gradually curving away from costa considerably before apex of cell, so that the apex of cell is far removed from costa; vein closing apical submarginal sloping backward, so that while the anterior portion of apex of the cell is at apex of marginal the posterior portion of apex is very much distad of it. Legs, especially the tarsi, with long soft white hairs, fore and mid tarsi with their joints short and broad; hind tarsi, except the apical joint, slender.

Length, 10–12 mm.

Type, Texas. No other data.

A female, with same data, which is in the collection may belong to this species. I append a summary of its characters:—

Differs in color from the male *acuta* in having the antennae rufous below and the wings more evenly yellow.

Structurally, differs in having the clypeus with a broad impunctate lower margin and its outline rounded; the oral opening extends even farther back, leaving but a narrow line between it and back of head; the first dorsal abdominal segment is shorter and broader, with the transverse median incision straight; the pygidium is covered on the entire surface with large, deep, contiguous punctures; the sixth ventral segment with the lateral margins conspicuously sinuate; the tarsi are less conspicuously hairy and are not so thick, and the basal joint of hind pair has a deep groove on posterior surface; and the venation differs in that the vein does not close the marginal cell.

Tiphia luteipennis Cresson

Mr. E. T. Cresson kindly furnished me with notes and sketches of the type specimen of this species, which enabled me to determine that *luteipennis* is distinguishable from the foregoing species by the following characters: oral opening broader; clypeus apparently smooth; pygidium punctate to apex, but the corresponding ventral segment much broader, with a broader impunctate margin and an almost regularly rounded apex (in *acuta* it is roundly emarginate); tarsi without long hairs at base, whereas in *acuta* there are long hairs which are most conspicuous on the mid pair.

Described from Colorado.

Tiphia canaliculata, sp. n.

Male.—Differs from *acuta* in having the antennae longer, the joints normal; the face more evenly punctured; clypeus broad at apex, regularly and broadly rounded, with a distinct impunctate margin; post-mandibular triangle distinct though small; the back of head, pronotum, and mesopleura with a few small punctures interspersed between the large ones; lateral margin of sixth ventral abdominal segment with two rounded incisions on each side, the central projecting part sharp; the

central groove on same segment deeper; the fore and mid tarsi normal in structure and not conspicuously hairy.

Length, 9 mm.

Type locality, Chimney Gulch, Col. (coll. N. Banks).

Female unknown.

Tiphia transversa Say

This species differs from all others known to me in having the tegulae much longer than broad in both sexes. In cephalic and thoracic punctuation the male very closely resembles that of *clypeata,* but the clypeus is slightly buccate centrally, its surface covered with large and microscopic punctures almost up to the anterior margin, the central portion narrower than one-third the clypeal width, tapered anteriorly and with a rather deep central emargination. The veins closing marginal and submarginal cells are nearly at right angles to the costa, whereas in *clypeata, inornata,* and most other species of this group, these veins are sloped diagonally towards the apex of wing posteriorly.

The female differs from *inornata,* in addition to the tegular distinction, in having the lateral areas of the metathorax distinctly punctate and the posterior face of metathorax smooth and doubly punctate, the large setigerous punctures being widely separated.

Originally described from Indiana. I have seen examples from Dubois, Algonquin, and Urbana, Ill., which are in the collection here, and from Falls Church and Great Falls, Va., Southern Pines, N. C., and Wollaston and East Falmouth, Mass., submitted by Nathan Banks. The dates on the specimens range from July 2 to September 3.

Two examples from Fedor, Lee county, Texas, one from Great Falls, and one from Falls Church differ from the others in having an impressed line above the outer margin of the tegulae which curves backward at two-thirds the length of tegula, whereas in the typical examples the line fades out and is not recurved.

The date of the Texas examples is June 21, 1909.

Tiphia clypeata Robertson

The male of this species is distinguished from all others known to me by the following combination of characters: Face with deep, large, contiguous punctures on lower half and sides, sparsely punctate in front of ocelli and with a narrow impunctate space centrally on upper portion; clypeus flat, doubly punctate except on a moderately broad border on apical central portion, this portion over one-third the width of clypeus, its outline transversely truncate; disc of pronotum and central portion of mesopleura with large deep punctures, the minute punctures absent; basal abdominal segment without transverse incision at middle, the preapical depression shallow, with 1–2 series of rather large punctures. Abdomen with rather large, deep, widely separated punctures;

apical dorsal segment with a central impunctate line which is faintly shagreened apically; marginal cell rather pointed at its outer posterior extremity, the enclosing vein sloped towards base of wing on its upper portion, second submarginal cell with its apex distad of submarginal.

The female, which has previously been undescribed, differs from that of *inornata* Say in the following characters:—

The clypeus is broader and not so high, with a less distinct central emargination; the mandibles are stouter and shorter, with the grooves extending much farther towards apex, the one on under side ending very close to apex; the basal dorsal abdominal segment has a better defined subapical depression, and has irregular, widely spaced punctures on basal half; and the pygidium has a smaller impunctate space which is more or less distinctly shagreened.

Originally described from Carlinville, Ill., and represented in my material by many specimens from various parts of this state, even to the northern tier of counties. I have also seen examples—from the collection of N. Banks—taken at Chain Bridge, Glencarlyn, and Falls Church, Va., and at Sea Cliff, N. Y. A female in the collections here, from Spokane, Wash., is either this or a closely allied species. The dates on specimens show that the species occurs from the middle of May till the middle of July, with a few scattered examples up to the middle of October.

Tiphia inornata Say

Tiphia vulgaris Robertson

The males of the above species very closely resemble each other, but may be separated as follows: *inornata* has the mandibles toothed, the clypeus with a rather large emargination, and the sixth ventral abdominal segment with the greater portion of its surface with long erect yellowish hairs; *vulgaris* has the mandibles almost invariably simple, the clypeus with a weak emargination, and the sixth ventral abdominal segment with shorter subdepressed white hairs.

The females are easily separated by the punctuation of the pygidium, which in *inornata* ceases about middle of disc, while in *vulgaris* it is carried to within a short distance of the margin. The last-named species is readily separated from its allies by the subopaque appearance of the ventral surface of the pronotum, due to the presence of many minute punctures between the larger ones. Both species have the basal half of first dorsal abdominal segment doubly punctate.

Both species occur throughout Illinois and in the Eastern States, *vulgaris* being the commonest species affecting white-grubs in the vicinity of Urbana. I have seen *inornata,* or a species which I can not separate from it, from Florida.

Both species appear to be largely confined to fields, especially pastures, and very few examples of either were taken in or near woodlands in 1917. At Galena, Ill., a series of both sexes of *vulgaris* was taken on

flowers of wild parsnip early in July. The greatest number of specimens of both species occurs in May, June, and the first half of July, but a few specimens occur much later every year.

I have before me several male specimens that do not exceed 6 mm. in length. These I thought at first represented a distinct species, but I consider it more probable that they are specimens which have been dwarfed through lack of food—a not uncommon occurrence among predaceous and parasitic species. To the food-habits of the species is also due no doubt some measure of the variability of punctuation and striation of the various parts of the body, just as in some Tachinidae the number of macrochaetae may vary considerably in large and small individuals of the same species, the difference in size being governed largely by the conditions under which the larval stages were passed.

Tiphia odontogaster Viereck

The male of this species differs from that of any other described species in having a sharp tooth-like tubercle on each side near posterior margin of ventral abdominal segments 3, 4, and 5. From *tuberculata* it differs in having the mesopleura with very large deep punctures and no interspersed minute punctures, the clypeus with a broad impunctate margin on central portion and the lateral angles of this portion reflexed, and the fore tibiae are black and much more slender, the apical dorsal abdominal segment is very coarsely punctured throughout, and the apical ventral segment has its postero-lateral outline deeply emarginate near apex so that the central protruded portion is nearly parallel-sided.

The female, hitherto unknown, may be described as follows:—

Glossy black, antennae brownish below, wings faintly yellowish.

Clypeus flat, central portion at apex hardly wider than socket of one antenna, punctures rather large and deep, impunctate margin moderately broad; apical antennal joint twice as long as subapical; facial punctures subcontiguous below, becoming more widely separated above; cheek glossy, punctures large and subequal, minute interspersed punctures present only near posterior margin. Disc of pronotum with large punctures; metathoracic enclosure with slender boundary and central ridges, surface of enclosure and of lateral areas of metathorax with very shallow pits or punctures; posterior surface of metathorax with very minute and larger, setigerous, punctures; mesopleura glossy, with large deep punctures. Basal abdominal segment short and broad; subapical depression poorly defined, centrally with 2–3 series of small punctures; pygidium punctate on basal half, rather coarsely shagreened and opaque on apical half; hairs on apical half of abdomen long and rather coarse.

Originally described by Viereck from a male collected at Beulah, N. M. The specimens before me, 1 male and 3 females, are from the collection of Nathan Banks and were taken at Palmerlee, Ariz., in September and October.

A male in the collection of the Illinois State Natural History Survey, collected at Las Vegas, N. M., and one from the collection of N. Banks, collected by A. Agassiz in the Gulf of Georgia, B. C., differ from the typical form in having only the tubercles on segment 5 tooth-like, the others being poorly developed—otherwise I can detect no specific distinctions, and I refer the specimens to this species tentatively.

Tiphia tuberculata, sp. n.

Male.—Glossy black. Antennal flagellum opaque black, usually paler below, occasionally yellowish brown towards apex on that side; palpi yellowish; mandibles pale from middle to tip. Legs black, anterior or inner side of fore tibiae, apices of mid tibiae, and the whole or a great part of all tarsi ferruginous or yellowish, tibial spurs pale. Wings clear at base, becoming brownish beyond middle and especially in the marginal cell; stigma and veins brownish black.

Punctures on lower portion of face of moderate size, contiguous, becoming more widely spaced above, ocellar region in small individuals sparsely punctate, no impunctate preocellar line present; scape of antennae closely punctate, the punctures small; clypeus flat, generally rounded or slightly transverse anteriorly in center, never emarginate, doubly punctate at base, the punctures large at apex and usually extending to extreme margin; mandibles without a well-developed preapical inner tooth; cheek minutely and closely doubly punctate. Pronotum with sparse, regular, moderately large punctures on disc; metathoracic enclosure well defined, never with a complete central ridge, the enclosed surface usually shagreened or faintly rugose; mesopleura with small punctures which are well separated, and between them many very minute punctures. Basal abdominal segment without median transverse incision; preapical depression broad and shallow, usually with 1–2, rarely 3, series of small punctures; second segment with very small widely separated punctures, remaining segments with closer and larger punctures, especially basally and apically; apical segment with a very narrow, faintly shagreened, impunctate central longitudinal line on apical half; fifth ventral abdominal segment with a distinct tooth-like projection, or a slightly elevated ridge, on each side near apex. Marginal cell very distinctly surpassing apex of second submarginal, its apex usually rounded; base of first cubital in nearly all cases distinct but short.

Female.—Differs from the male in having the fore tibiae entirely black, and the tarsi usually less noticeably yellowish.

The clypeus is regularly broadly rounded or subtruncate centrally at apex and punctured except on a narrow apical margin; the face is closely and minutely doubly punctate below, becoming more coarsely and gradually more widely punctate above; cheeks doubly punctate on posterior half; mandibles simple. Mesopleura with rather small, widely separated punctures, the spaces between microscopically shagreened and

with very minute pits, giving the whole a subopaque appearance very different from the glossy surface of allied forms; sides of metathorax rather coarsely shagreened even where rugose. Abdomen punctured as in the male but the punctures larger and closer; pygidium impunctate on apical half, the punctures rather abruptly ceasing in a transverse line, apical half very faintly shagreened, distinctly glossy; second ventral segment quite as distinctly shagreened as the others, which is not the case in allied species.

Length: male, 5.5–7 mm.; female, 6–8.5 mm.

Type locality, Meredosia, Ill., August 19–22, 1917, collected by sweeping the foliage of black-jack oak along margin of a sand-pit.

Paratypes and allotypes: Dubois, Ill., August 8, 1917, collected by sweeping foliage of black-jack oak; Havana, Ill., August 30, 31, 1917, collected by sweeping foliage of various trees in the sand region near Havana; Bluffs, Ill., Aug. 19, 1917. Collectors, T. H. Frison, C. A. Hart, and the writer. Over 100 specimens.

Tiphia subcarinata, sp. n.

Male.—This species agrees very closely with *tuberculata,* but is larger, averaging 8 mm. in length, and has the second ventral segment glossy, showing none of the fine shagreening which is present in *tuberculata,* even under a strong magnification.

The color of the legs and antennae is the same in both species, and both have an impressed line on margins of the tegulae. The post-mandibular triangle is shagreened in both species. In *tuberculata* the protuberances on sides of fifth ventral segment are usually tooth-like, while in *subcarinata* they are in the form of short transverse ridges.

Type locality, Glencarlyn, Va., July 25, on Ceanothus. Paratypes: same locality as type, June 23 and 30 and July 25; Great Falls, Va., June 28 and July 8; Falls Church, Va., August 13 (N. Banks); Grand Junction, Mich., July 15, 1914.

Tiphia rugulosa, sp. n.

Male.—Entirely black, glossy. Wings slightly grayish, veins black.

Face on almost its entire surface with large, deep, contiguous punctures, with none which are very minute, a distinct raised central ridge on lower half of face extending to, or almost to, an impunctate line which reaches the anterior ocellus; ocellar region sparsely punctate except on vertex; scape of antennae glossy, the elongate joint coarsely punctate, flagellum opaque; clypeus glossy, slightly buccate centrally, and with large punctures, broadly depressed and impunctate apically, the margin with slightly reflexed angles; cheeks doubly punctate. Pronotum with large, distinctly separated punctures on disc except along posterior margin; scutellum and postscutellum with large punctures; lateral margins of metanotum rugose; enclosure usually with a distinct raised central line and weak transverse rugose reticulations; mesopleura

with large punctures on entire surface, minute punctures either absent or present on margins only. Basal dorsal abdominal segment without median transverse incision, preapical depression broad and shallow, usually with 3 rows of rather large punctures, the punctures sparse proximad of the depression, becoming much more numerous towards middle; next 4 segments with large shallow punctures; apical segment rounded, without sharp ridge, rather coarsely punctate except on apical half of center of dorsum, the impunctate area microscopically shagreened, giving it a subopaque appearance; hairs on abdomen of moderate length, those on apical ventral segment not more dense than on subapical; marginal cell truncate or subtruncate apically; second submarginal elongate, its apex distinctly proximad of apex of marginal.

Female.—Differs from the male in having the facial punctures widely separated, the clypeus flat on disc, with the impunctate margin broader and its apex less reflexed, and the punctures on thorax and abdomen more widely separated, and on the latter much smaller.

Differs from other Eastern species known to me in having the pygidium impunctate and minutely shagreened on apical half.

Length: male, 7.5–9 mm.; female, 8–9.5 mm.

Type locality, Urbana, Ill., November 10, 1915, male taken in forestry of the University of Illinois (J. R. Malloch). Allotypes: Urbana, university grounds, June, 1885 and 1888 (J. Marten); Homer, Ill., July 20, 1907 (C. A. Hart). Paratypes and allotypes: Falls Church, Va., September 17 to October 11; Glencarlyn, Va., October 7; Great Falls, Va., October 3 (N. Banks); Wollaston, Mass., June 1, 1895 (F. Sprague).

Tiphia clypeolata, sp. n.

Female.—Resembles *punctata* Robertson, but differs strikingly in the form of the clypeus, which is flat and has the central portion with a rounded excavation, the edge of which is almost declivitous. The upper portion of head except immediately above the antennae is very sparsely punctate, the punctures being small; the mandibles are large, and broad almost to apex. Pronotum with small sparse punctures on dorsum; tegulae simple; lower portion of sides of metathorax weakly striate and with faint setigerous punctures, posterior surface doubly punctate. Basal dorsal abdominal segment with a broader, but still deep, post-marginal incision; no marginal incised line on any of the segments; pygidium glossy on apical half. Groove on basal joint of hind tarsi short, poorly defined. Stigma small, truncate, radius leaving at its apex or close to it.

Length, 12–14 mm.

Type locality, Fedor, Lee Co., Texas, April 28, 1909 (coll. Banks). Paratype, Pennington Gap, Va. (coll. Banks).

I have before me six specimens of what I take to be the male of this species. They are very similar to the male of *punctata*, but differ in having the clypeus flat, punctate to apex, and with a rounded central emargination. The upper portion of head and the dorsum of pronotum

are more densely punctate than in *punctata*, but in other respects they agree very closely in the two species.

Length, 7–9 mm.

Localities, Falls Church, Va., September 28 and 29, and Dubois, Ill., August 10, 1917.

Tiphia incisurata, sp. n.

Female.—Black; under side of flagellum, mandibles except bases and apices, and palpi brown.

Facial punctures subcontiguous above antennae, elsewhere widely separate; clypeus with the punctures becoming larger towards apex and extending to margin, the latter transverse; space between oral opening and back of head broad; post-mandibular triangle sparsely punctate. Pronotum with large punctures on greater portion of sides; mesopleura coarsely, doubly punctate; posterior face of metanotum minutely punctate, with a few shallow, large punctures near upper lateral angles. Basal dorsal abdominal segment with an almost straight transverse median incision, anterior declivitous portion very minutely punctate in center, with large punctures laterally, posterior dorsal portion of segment with sparse punctures and no clearly defined post-marginal depression; incised line on posterior margin of segments 2 to 5 distinct; pygidium impunctate on apical half, its surface smooth. Incision on posterior surface of basal joint of hind tarsi small, almost punctiform, the surface irregularly punctate. Stigma rather large, radius leaving before its apex.

Length, 11.5 mm.

Type locality, Southern Pines, N. C., June 23, 1910 (A. H. Manee).

Tiphia occidentata, sp. n.

Male.—Glossy black. Apices of mandibles and the palpi yellowish brown. Antennae entirely black, flagellum opaque. Wings slightly grayish, veins black. Hairs white.

Face with deep, large, contiguous punctures which become more widely spaced as they near vertex; a narrow impunctate space below anterior ocellus connects with a sharp elevated central ridge which does not reach entirely to antennal insertions; clypeus convex in center, doubly punctate on disc, the minute punctures sparse, apex with a narrow impunctate flat rim which is deeply emarginate centrally; mandibles with poorly developed subapical tooth; back of head coarsely and very closely doubly punctate. Dorsum of pronotum with very large contiguous punctures; mesopleura with large, deep subcontiguous punctures, metathoracic enclosures with sharp boundary and central ridges; declivitous lateral portions of metathorax coarsely rugose above, faintly longitudinally striate below and with a number of rather large shallow punctures near lower margin; posterior face of metathorax coarsely rugoso-reticulate. Basal dorsal abdominal segment without median

transverse incised line, the punctures large, becoming sparse near apex, subapical depression broad and shallow, with two series of punctures centrally; punctures on segments 2 to 6 large and deep, becoming progressively larger and closer to sixth, on which they are subcontiguous; seventh segment with large, deep contiguous punctures and narrow longitundinal impunctate line on apical half; fourth and fifth ventral segments each with a poorly developed tubercle on each side near posterior lateral angle. Wing venation similar to that of *inornata,* the apex of marginal cell at upper anterior angle of submarginal, and very distinctly proximad of lower anterior angle; angulation of radius less than one-third of the distance from stigma to first transverse cubital.

Length, 9.5 mm.

Type locality, Colorado. One specimen labeled "Mts. of Colo., Aug.–Sept., Carpenter." (Coll. N. Banks.)

Tiphia similis, sp. n.

Male.—Differs in color from *occidentata* in having the mandibles and palpi darker and the wings whitish.

Face with less closely contiguous punctures on lower portion than *occidentata,* the preocellar impunctate space indistinct and the central ridge usually absent; clypeus doubly punctate, disc slightly convex, apical impunctate margin of moderate width, central emargination much less pronounced than in *occidentata;* mandibles simple; back of head glossy, the large punctures well separated, the minute punctures not very numerous. Pronotum with punctures separated and equal in size to those of mesopleura, the latter doubly punctate on margins and rather broadly so posteriorly; posterior face of metathorax with rather small close punctures; lower half of sides of metathorax with longitudinal striae, but without the punctures present in foregoing species. Abdomen similar to that of *occidentata,* but with less conspicuous hairs, no tubercles on ventral segments, and the seventh dorsal segment with larger punctures and an impunctate central line; first dorsal segment much more rounded above, with a very deep post-marginal incised line, and the depression between the first and second segments very much deeper. Apex of marginal cell in line with apex of submarginal, the lower angle of latter proximad of median portion of posterior margin of cell; angulation of radius about two-fifths of the distance from stigma to transverse cubital.

Length, 8 mm.

Type locality, Waukegan, Ill., August 25, 1917 (J. R. Malloch).

A specimen in our collection differs from the type in having the legs paler, the wings almost milky, the stigma largely yellowish, the impunctate line below anterior ocellus present, and the clypeus narrow and with a less distinct margin. In other respects it agrees with the type, and I consider it as the same species.

Locality, Cherry Valley, Ill., Aug. 17, 1883.

Tiphia affinis, sp. n.

Male.—Very similar to *similis,* differing only in having the disc of mesopleura usually with a few scattered small punctures interspersed between the large ones, the face with a very distinct central ridge, the clypeus broader, lower portion of sides of metathorax shagreened, second dorsal abdominal segment precipitous anteriorly so that there is a very pronounced incision between the first two segments.

Female.—Differs from the male in having the antennae ferruginous apically, and the under side of antennal flagellum of same color.

Face narrowly doubly punctate above antennae, remainder of surface with sparse large punctures: clypeus doubly punctate basally, impunctate on a broad apical margin, centrally narrowly emarginate; mandibles simple, broad, grooves ceasing some distance before apex; cheeks, posteriorly, narrowly doubly punctate above. Mesopleura glossy, doubly punctate posteriorly; enclosure parallel-sided, well defined, central ridge distinct; posterior face of metathorax doubly punctate laterally. Basal abdominal segment with very small sparse punctures, preapical depression consisting of a single transverse series of deep contiguous punctures; anterior margin of second segment not so noticeably declivitous as in male, but more so than in females of other species; remaining segments sparsely covered with small punctures, which are closer near anterior and posterior margins; pygidium with the apical half glossy and impunctate. Stigma small, truncate, outer transverse cubital oblique. Basal joint with groove on posterior surface weak—in the form of two small subcontiguous pits.

Length: male, 6–7 mm.; female, 7 mm.

Type locality, Galena, Ill., July 8, 1917 (Hart and Malloch). Paratypes: Falls Church, Va., July 1–4 (N. Banks); Dubois, Ill., Aug. 10, 1917 (J. R. Malloch).

Tiphia aterrima, sp. n.

Female.—Glossy black; flagellum below, and mandibles except apices ferruginous; front side of fore tibiae and the tarsi brownish.

Head rounded above; the front slightly buccate above antennae and not steeply declivitous above, sparsely punctate above, punctures below not contiguous; clypeus with a broad impunctate margin, apex slightly, narrowly emarginate; mandibles simple, long; space between oral opening and back of head broad. Metathorax twice as long as scutellum, shagreened and sparsely punctate on dorsum; enclosure 3 times as long as broad, parallel-sided or slightly narrowed centrally; lower portion of sides of metathorax distinctly shagreened, posterior face doubly punctate. Anterior declivitous portion of dorsal abdominal segment doubly punctate on entire surface, the small punctures very minute; post-marginal depression broad, with 2–3 series of large punctures except in center; punctures on remaining segments as in *punctata,* the post-marginal incised line distinct except sometimes on median portion of second seg-

ment; pygidium glossy on apical half. Legs normal, hind tarsal groove long.

Length, 8 mm.

Type locality, Urbana, Ill., Sept. 6, 1891 (C. A. Hart). Six specimens.

Tiphia arida, sp. n.

Female.—This species closely resembles *punctata,* but differs in having the tegulae with an incised line on a large part of outer margin. the basal dorsal abdominal segment with a rather shallow, broad post-marginal depression in which there are 2 rows of punctures centrally, and a large median patch of small punctures on the declivitous anterior half of segment, which extends caudad almost to the post-marginal depression. The incised line on posterior margin of abdominal segments is present only on lateral portions of segments 2 and 3 but complete on 4 and 5. The pygidium is irregularly wrinkled and indistinctly shagreened on basal portion of apical half. The hind tarsal groove is long and deep. Radius leaves stigma at apex of lower side, the apex of stigma oblique. Otherwise as *punctata.*

Length, 11.5 mm.

Type locality, Havana, Ill., Aug. 13, 1903 (C. A. Hart). Taken at a place called Devil's Hole.

Tiphia texensis, sp. n.

Female.—Agrees in most respects with *punctata,* but is larger, generally exceeding 15 mm. in length. The metathoracic enclosure is somewhat lyre-shaped, the lateral ridges being bent inward at middle, cephalad of which they are curved outward and then, just at anterior margin, they curve inward again. The lower part of sides of metathorax have 2–3 large punctures close to lower margin, but are otherwise as in *punctata.* The basal dorsal abdominal segment is similar to that of *punctata,* but the second is more regularly covered with larger punctures. The shagreening on pygidium is very minute and becomes obsolete before reaching apex.

Type locality, Dallas, Texas. Four females. (Coll. N. Banks.)

Tiphia punctata Robertson

I have examined the type specimen of this species. In my material here I have a very large number of males and a smaller, though still large, number of females which I consider belong to the species. There are some slight differences between the male examples from the various localities but, while I think that there are several species in the lot, I do not consider it advisable to attempt to differentiate them with the specimens I have as criteria. So closely related are the forms that it is not impossible that what I regard as probably distinct species are merely local variants of one and the same species. For the present, then, I leave

all the males as *punctata,* though I may have males of some of the closely related species confused with them.

The characters used in the keys and the differences cited in the descriptions of other species should serve to identify this species.

The female has not been described. It differs from *robertsoni* in having the basal dorsal abdominal segment with a very slender linear post-marginal incision, and the lower half of sides of metathorax with very faint shagreening.

Common throughout Illinois, and represented in my material by specimens from Virginia and New York.

Occurs from July to September inclusive.

Tiphia punctata var. intermedia, var. n.

Female.—This variety differs from the typical form in having the pygidium with distinct shagreening on a large portion of the apical half. In other respects it is very similar though averaging smaller, being 9–11 mm. in length.

Type locality, Carlinville, Ill. (Robertson). Paratypes: Falls Church, Va., July 10–Sept. 17; Washington, D. C.; Taunton, Mass.; Great Falls, Va., August 24.

Tiphia tegulina, sp. n.

Female.—Black, shining; under side of flagellum, middle of mandibles, and palpi ferruginous.

Head broad, flattened above, face almost transverse when viewed from above, lower portion sparsely punctate, upper portion with widely separated punctures; clypeus with a broad impunctate apical margin, the outline transverse. Sides of pronotum coarsely striated except above; mesopleura glossy, with sparse irregular punctures; posterior face of metanotum doubly punctate; tegulae large, with a distinct marginal incised line. Declivitous portion of first dorsal abdominal segment doubly punctate, the posterior portion sparsely punctate and with a very broad poorly defined post-marginal depression; incised line on posterior margins of segments 2 to 5 distinct except in center of 2; pygidium minutely and indistinctly shagreened on apical half. Groove on posterior surface of basal joint of hind tarsi long and deep. Stigma large, radius leaving before its apex.

Length, 13.5 mm.

Type locality, Goose Lake, Siskiyou Co., Calif. (coll. Banks).

A specimen from Wenass Valley, Washington, July 7, 1882, may represent a distinct species. It is smaller, 9 mm. in length, and is less distinctly punctured, especially on dorsum of pronotum and anterior portion of basal dorsal abdominal segment. It differs from the following species in the greater separation of the oral opening from the back of the head.

Tiphia conformis, sp. n.

Female.—Very similar to *tegulina,* differing in being smaller, and in having the face less distinctly transverse, with contiguous large punctures on the lower half and more closely placed punctures above. The space between oral opening and back of head is much narrower than in *tegulina.* The upper half of sides of pronotum is less conspicuously striated, and the posterior face of the metanotum is densely covered with minute punctures and the larger punctures are irregularly arranged on surface. The basal dorsal abdominal segment is less densely covered with minute punctures. In other respects similar to *tegulina.*

Length, 11 mm.

Type locality, Quincy, Ill., August 13, 1889, taken on thistles, etc. (C. A. Hart). Paratype, Falls Church, Va., August 2 (N. Banks).

A female in the collection from Brownsville, Texas, November 24, 1911, differs from the type in having the basal dorsal abdominal segment almost without minute punctures in center, but agrees in other respects very well with the type.

A male taken at the same time as the type resembles *punctata* Robertson, but differs as indicated in the key.

Tiphia imitatrix, sp. n.

Female.—Very closely resembles *conformis,* but differs in being much smaller, as indicated in key. In addition to the difference in size there are distinctions in the head structure, the space between the oral opening and the back of head being greater in *imitatrix* than in *conformis.*

Type locality, Falls Church, Va., Aug. 24, 31, and Sept. 13 (N. Banks).

Tiphia egregia Viereck?

I identify doubtfully as this species a large number of male specimens taken in the following localities: Falls Church, Va., Aug. 7, 30, 31 (Banks); Bluffs, Ill., Aug. 19, 1917; Meredosia, Ill., Aug. 19–22, 1917; Havana, Ill., Aug. 30, 1917 (Malloch).

Tiphia inaequalis, sp. n.

Male.—Closely resembles *affinis,* differing only in having the clypeus more elevated centrally, the face less distinctly carinate in center, the basal dorsal abdominal segment less declivitous posteriorly and with a slight but distinct constriction of the deep post-marginal incision, and the anterior margin of second segment not abruptly declivitous anteriorly.

From *egregia* it differs as indicated in key.

Female.—I can not separate this sex from the female of *affinis.*

Length, 6.5–7.5 mm.

Type locality, Dubois, Ill., Aug. 9, 10, 1917 (Malloch). Paratypes: Ashley, Ill., Aug. 7, 1917, White Heath, Ill., Aug. 8, 1915 (Malloch); Falls Church, Va., July 8, 9, Aug. 7–9, Sept. 29 (Banks).

This may be *relativa* Viereck, but it is not possible to decide without comparison of the types.

Tiphia robertsoni, sp. n.

Female.—Larger than *affinis,* resembling in most respects *punctata,* from which it differs in having the lower half of sides of metathorax very distinctly shagreened or cross-striated. The basal dorsal abdominal segment has a poorly defined post-marginal depression in which there are 1–3 series of deep punctures; the anterior declivitous portion of this segment is doubly punctate on a large portion of center of disc; and the pygidium is smooth on apical impunctate space, which is smaller than in *punctata.* For other characters see key.

Length, 10.5–11.5 mm.

Type locality, Carlinville, Ill., August (C. Robertson). Paratypes: Urbana, Ill., July 23, 1891, Sept. 9, 1892, and Aug. 30, 1914; Muncie, Ill., Sept. 7, 1912; Alto Pass, Ill., Aug. 12, 1891; and Falls Church, Va., Sept. 6 and 10 (Banks).

Tiphia winnemanae, sp. n.

Male.—Very closely related to *punctata,* but readily separated from it by the characters mentioned in the accompanying key. The tegulae in *punctata* usually have on the posterior margin a distinct incised line, but very rarely if ever in typical specimens is it carried forward along the outer margin. In those cases where such line occurs the much coarser and closer punctuation of the mesopleura should serve to separate the species.

Length, 7.5 mm.

Type locality, Plummers Island, Md., July 24 (N. Banks).

Tiphia reticulata, sp. n.

Female.—Closely related to *punctata,* separable by the very distinctly shagreened ventral surface of thorax, even the posterior flap-like extension of the mesothorax being so distinctly reticulated as to appear almost subopaque. The clypeus is flat, rather broad and low, with a broad impunctate margin and a rounded central emargination. The pygidium is distinctly but not coarsely shagreened. Tarsal groove long and deep.

Length, 8.5 mm.

Type locality, Falls Church, Va., Sept. 29 (N. Banks).

Tiphia floridana Robertson

I have examined the type series of this species. I can not distinguish very striking differences between this species and *waldeni* Viereck, and

consider that they may possibly be the same. The male sometimes has the tubercle absent from basal dorsal abdominal segment.

Tiphia illinoensis Robertson

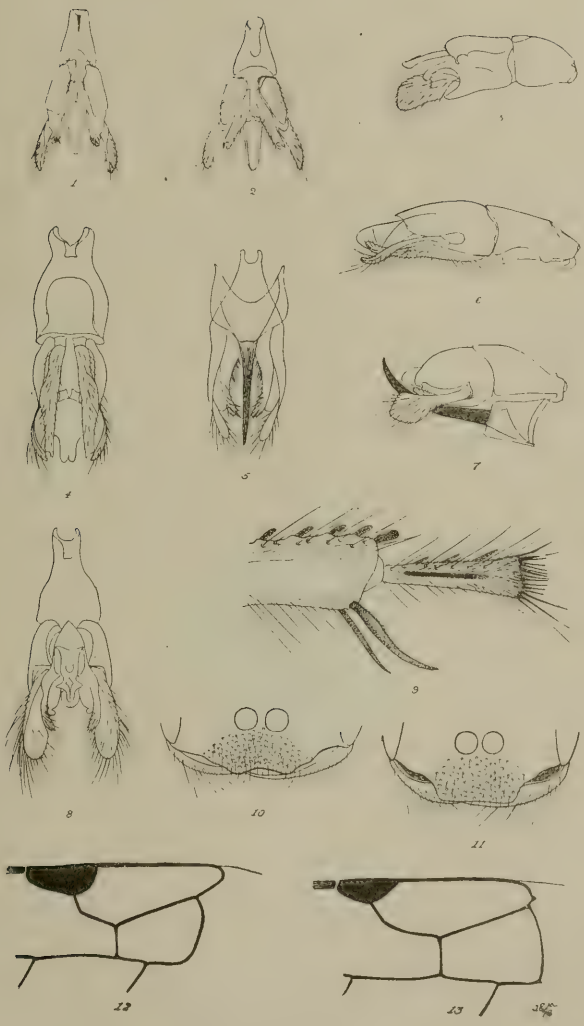
I have seen only the male of this species, which is distributed widely throughout Illinois. Robertson made no mention of the median transverse incision of first abdominal segment in his description, but the type specimen possesses this character, as also do several other specimens in the type series. Mixed with the type series were several specimens of *punctata*, the type of the latter being so much larger that they were not associated with it.

Plate I

Fig. 1. *Paratiphia algonquina*, hypopygium of male, dorsal view, with eighth ventral segment removed.
Fig. 2. The same, ventral view.
Fig. 3. The same, lateral view.
Fig. 4. *Neotiphia acuta*, hypopygium of male, ventral view, with eighth ventral segment removed.
Fig. 5. *Tiphia punctata*, hypopygium of male, ventral view, eighth ventral segment in position.
Fig. 6. The same as Fig. 4, lateral view.
Fig. 7. The same as Fig. 5, lateral view.
Fig. 8. *Tiphia transversa*, hypopygium of male, ventral view, with eighth ventral segment removed.
Fig. 9. *Tiphia punctata*, apex of tibia and basal joint of tarsus of hind leg, caudal view.
Fig. 10. *Tiphia inornata*, clypeus of male.
Fig. 11. *Tiphia clypeata*, same.
Fig. 12. *Tiphia inaequalis*, marginal and submarginal cells of wing.
Fig. 13. *Tiphia inornata*, same.

October 1, 1918.

PLATE I



STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
DIVISION OF THE
NATURAL HISTORY SURVEY
STEPHEN A. FORBES, Chief

Vol. XIII. BULLETIN Article II.

WAYS AND MEANS OF MEASURING THE DANGERS OF POLLUTION TO FISHERIES

BY

VICTOR E. SHELFORD

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
September, 1918

Schnepp & Barnes, State Printers
Springfield, Ill.
1918.

8525—1200

ARTICLE II.—*Ways and Means of measuring the Dangers of Pollution to Fisheries.* BY VICTOR E. SHELFORD.

INTRODUCTION

We are at war with a powerful and well-organized nation which has planned and saved with war in view. In our belated endeavor to conserve existing resources and to develop new and latent ones new problems are constantly arising. Some of these concern fisheries and the pollution of waters. The U. S. Fish Commission is urging the public to eat fish—to make every day a fish day. This was no doubt done in the early days of our republic, for in a great strike of apprentices one of their chief demands was that they be not fed on salmon more than three times a week. The richness of the fish supply of our eastern states in their early colonial days and for a considerable time thereafter is said to have exceeded our wildest imagination. Meehan ('17) quotes an early writer who said of the shad in the Susquehanna and Delaware Rivers: "They came in such vast multitudes that the still waters seemed filled with eddies, while the shallows were beaten into foam by them in their struggles to reach the spawning grounds." They swarmed every spring from mouth to headwaters of every river from Maine to Florida. Shad was undoubtedly the most important food fish in the early days of our nation; they were eaten fresh, and smoked and salted for winter use. During the spring runs people traveled long distances to shoal waters to obtain their winter's supply (Meehan, '17).

Along the Illinois River many years ago buffalo-fish afforded the chief marketable species. These were caught by farmers, fishermen, and others, and shipped by boat, principally to St. Louis. As no ice was used the fish frequently spoiled, or they were thrown away because the market was overloaded. Thus this great resource was depleted by careless and wasteful methods of catching and marketing (Bartlett, '17). For a brief discussion of more recent decrease of buffalo-fish in the Illinois River see Richardson, '13a, p. 409.

The Atlantic salmon once entered all the rivers of New England; now it is the most expensive fish on the market. Our Great Lakes once yielded whitefish in abundance, but now the number is exceptionally small in comparison. Some of our Pacific-coast fisheries are likewise being depleted. Every stream formerly yielded fish to small boys and old-men anglers. If any of these sources yielded half their original quantity it would now be counted a veritable fortune in fish.

Our fish resources have been depleted through neglect, carelessness, and the pollution of waters. Such as are still left are endangered by

new projects and new pollutions. There has been too much bald scientific and business sophistry in the matter. Ichthyologists, biologists, engineers, sanitarians, industrial chemists, and business men, without consultation, cooperation, or critical analysis, have proceeded on the basis of their imperfect and fragmentary knowledge to draw inferences as to the effect of this or that on fishes. The inferences of some scientists are not especially more in keeping with an equitable decision relative to a policy favorable to the public interest than was the exclamation of a manufacturer when confronted with a law intended to stop his factory from polluting streams: "What! stop a great industry because of a few fish!" The pollutions of manufacturing plants and city sewage have greatly aggravated the depletion, or in some instances have completed the destruction, previously started by heedless fishermen; but the pollutions are far more serious than the initial injury because they preclude the possibility of easy recovery. We have all sinned alike until it becomes imperative that we take stock of our knowledge, now that we are under the pressure of numerous problems demanding immediate solution because of the great war. Some means of approximately measuring the harm which pollutions do, is needed at once. Our knowledge of the subject is incomplete and unorganized. A number of crucial questions have frequently called for answers in the past few months, and it is the purpose of this paper to state these problems, to emphasize the need for further definite investigation for their solution, and to give a general indication of the trend of existing data bearing on them. The general subject of the relation of aquatic animals to the physical and chemical conditions of their environment has only recently begun to receive systematic attention. (Birge and Juday, '11; Forbes and Richardson, '13; Shelford, '17, '18.) The tables here included are provisional and incomplete, but they indicate what kind of tables would be found highly useful were the data for them in hand, and they also indicate the pressing need for further investigation.

The writer wishes to express here his indebtedness to Mr. E. B. Powers and Mr. W. D. Hatfield for assistance in preparing this paper.

Nine Crucial Questions in Connection with Problems of Pollution in Relation to Useful Aquatic Animals

On the basis of the author's personal studies, an examination of the literature of the subject, and discussion with persons engaged in several related lines of investigation, an attempt is here made to point out means of answering nine crucial questions, relating to the survival, well-being, abundance, and quality of useful aquatic animals, which are intimately associated with the question of the economical use of wastes and the satisfactory disposal of such effluents as can not be worked up. But the final practical solution of so complex a problem calls for something more than a knowledge of the toxicity of wastes and the best methods for determining it, and insistence on the preservation of food and breeding

grounds; it imperatively demands that in calculating values a standard shall be set which applies to the country as a whole rather than to a mere group of individuals (Austin, '17).

I. Is the animal used in testing the toxicity of a polluting substance one of representative sensitiveness?

The resistance of different useful aquatic animals to polluting substances varies greatly, as does also that of their living food. In the case of fish, for example, it is not sufficient to secure for making tests *any* fish that may be convenient. The fish used should be one of the more sensitive ones. The tests of toxicity must of course be of a character to determine means of affording protection to fish, but not to fish alone; the organisms on which they feed are commonly more sensitive than the fishes themselves.

The following table gives an estimate of the relative resistance of several widely distributed species of North American fishes. While it needs careful verification by new methods, it will serve as a rough provisional guide. It is based largely on death in waters containing little oxygen and much carbon dioxide. Since fishes rank differently in resistance according to the poison in which they are killed (Shelford, '17, p. 408), the immediate need for further investigation is obvious.

TABLE I

Indicating the relative resistance of a very sensitive minnow and of some common game-fishes of the eastern and central United States and of the goldfish. The resistance of the least resistant species is arbitrarily taken to be unity. (After Wells, '18, except the orange-spotted sunfish and the goldfish.)

Species of fish	Relative resistance	Species of fish	Relative resistance
Labidesthes sicculus (Brook silverside)	1.	*Ambloplites rupestris* (Rock bass)	10.
Moxostoma aureolum (Red-horse)	2.3	*Perca flavescens* (Yellow or American perch)	10.
Catostomus commersonii (Common sucker)	2.4	*Lepomis humilis* (Orange-spotted sunfish)	12.
Micropterus dolomieu (Small-mouthed black bass)	5.	*Carassius carassius* (Goldfish or Crucian carp)	12.
Micropterus salmoides (Large-mouthed black bass)	6.	*Lepomis cyanellus* (Blue-spotted sunfish)	15.
Pomoxis annularis (White crappie)	8.	*Ameiurus melas* (Black bullhead)	45.
Pomoxis sparoides (Black crappie, Calico bass)	8.		

Choice of Animals used for Tests.—The common suckers, *Catostomus commersonii* Lac. or *Moxostoma aureolum* Le S. are recommended

as suitable fresh-water animals for tests. They are widely distributed, easy to obtain, and easy to recognize, and are representatively sensitive (Forbes and Richardson, '08). It is also comparatively easy to determine accurately when an individual is dead. Powers found that to touch the tip of the tail of a fish to HCl would determine whether or not it was dead. As a representative fish food fresh-water shrimps (Palaemonetes) may be used; they live all the time under water and fall over readily when overcome, and the movement of the gill-bailer can be readily seen and serves to show when death occurs. Shrimps are also good in marine work (Shelford, '16, '16a). *Hyalella knickerbockeri*, a common, small fresh-water amphipod, is perhaps one of the most widely distributed fish foods, and as it is sensitive it will serve as a test animal for fish foods.

Amount of Water.—Experience has shown that about one liter of water should be used for each two grams' weight of individuals tested. With non-volatile substances the diameter of the surface exposed should be about equal to the depth of the water (Marsh, '07; Shelford, '17; Wells, '18; Powers, '18). Volatile substances should be added to running water (Shelford and Allee, '13; Shelford, '17; Wells, '18).

Time to Death.—For comparisons of toxicities, concentrations which kill the animal in from fifty minutes to two hours should be used (Shelford, '17; Powers, '18); for the short experiments, the temperature should be constant; and for safety tests, the fish should live for about a month in the water. After two days in the small quantity of water, for long experiments the animal should be transferred to aquaria with two liters of water for each gram of fish (Marsh, '07).

II. What is the most sensitive stage in the life history of the test animal and of any useful animal associated with it?

Tests of the minimum quantity of poison which will prove fatal must be made on the most sensitive stage. The strength of a chain is the strength of its weakest link. After a fish or other animal of representative resistance has been chosen, the results of tests have little or no significance until *the most sensitive period* in the life history has been determined. Of what importance is it merely to know that three parts of naphthalene per million will kill an adult fish in one hour if some other stage is twice as sensitive? From this point of view only a little has been accomplished in the study of poisons; the most sensitive period is not known for a single species of which the entire life cycle has been definitely studied (Wells, '16). It has merely been determined that to nearly all toxic substances the younger or smaller fish, down to the smallest fry, are more sensitive than older ones, and Child ('15) has found that in the case of Tautogolabrus the resistance of the egg falls gradually from the time of fertilization to the time of hatching, when a slight rise occurs. His experiments were discontinued at this point. Investigation of the minimum quantities of substance which will prove detrimental is useless unless the experiment is conducted on the most sensitive stage. A

twenty-gram rock bass may be fifty to one hundred times more resistant than the most sensitive stage in the egg or fry. This might be a safe guess for shrimps also. To meet Illinois problems alone, there is immediate need for a study of the entire life-cycle resistance of the suckers.

Choice of Stages to be tested and Frequency of Tests.—The early stages should be tested at very short intervals. Artificially fertilized eggs should be divided into lots and tested at intervals of fifteen minutes to several hours (Child, '15, pp. 412–416).

TABLE II

Showing differences in sensitivity of various stages of several marine and fresh-water animals. Most sensitive stage rated as 1. No basis for a comparison of the species. Whitley's results are not comparable with those of the others, as his experiments showed only abnormal development.

Species	Poison	Relative resistance of different stages		Observer
Starfish	KCN	Unfertilized egg	9.00	Child ('15)
		Blastula to gastrula	1.00	
		Young bipinnaria	2.00	
Sea-urchin	KCN	Unfertilized egg	3.88	
		Early gastrula	1.00	" "
		Prepluteus	1.50	
Clam-worm	KCN	2–4 cell stage	18.00	
		Larva with 2 pairs of setae	1.00	" "
		Advanced larva	3.30	
Killifish	Phenyl urethane	2-cell stage	6.00	" "
		Hatching	1.00	
Tautogolabrus	Phenyl urethane	15 min. after fertilization	43.00	" "
		Heart beating	1.00	
		Newly hatched	1.25	
Plaice eggs	Acid	Fresh-laid	1.00	Whitley ('05)
	Acid	10 days old	10.00	
Plaice eggs	Alkali	Fresh-laid	1.00	" "
	Alkali	10 days old	2.00	
Rock bass	CO_2 and low O_2	1.9 gram	1.00	Wells ('13)
		20–40 grams	5.00	
Common shiner	CO_2 and low O_2	0.6 gram	1.00	" "
		21.0 grams	3.00	

Concentrations and Time to Death.—Tests should be made on each stage with five concentrations of the poison. Time-concentration curves should be plotted, reciprocal curves constructed (Krogh, '14; Powers, '18), and the comparisons made should be based on concentrations within which the rate of killing is regular.

III. When is the pollution most concentrated?

In fresh water, pollution will, as a rule, be most concentrated during seasons of drought or in extreme low-water in winter; but to this rule there are many exceptions. Pollutions which float will do most damage during storms or high winds. This source of danger is greatest in the sea.

Effect of Winter Ice.—Ice in winter prevents aeration and hinders circulation, and seems to have been responsible in Illinois for important losses of fish due to pollution (Hansen and Hilscher, '16, '16a).

Effect of Temperature.—Many poisons are more toxic at high temperature than at low (Warren, '00). Results soon to be published by Powers confirm Warren's conclusions. Experiments should generally be carried on when the water in question is at the usual seasonal temperature, though some tests should always be made at its maximum temperature. Some of the relative-resistance work on adult fishes at different seasons of the year may have been vitiated to some extent by too little regard to the temperature factor, thus yielding somewhat exaggerated differences of resistance in the comparisons made (Wells, '16). Temperature has direct effects also (Wells, '14).

Effect of Oxygen.—An abundant supply of dissolved oxygen reduces the toxicity of some substances—of CO_2, for example (Wells, '13; Shelford, '18b).

IV. What is the toxicity of untreated polluting effluents; of each residual of processes of partial recovery; or of treatment by additions to the effluent?

One essential in dealing with pollution problems lies in the determination of the toxicity of the various constituents of the polluting substance and of the wastes or residues resulting either from operations—present or prospective—for the recovery of useful substances or from methods of treating the effluent. This is imperative, for partial-recovery methods may give rise to substances as residues or secondary by-products which are as toxic as the original waste, or even more so. As a case in point I may mention a personal study of a large series of representative constituents of gas wastes which I began in 1914. This investigation showed that all the essential components are so highly toxic that no method of *partial* recovery can be relied upon to protect fishes. The least suspected substances, some rated as insoluble, were among the most toxic —for example, CO, benzene, and naphthalene (Shelford, '17; Wells, '18).

The proposed plan of treating the sewage of Boston and Chicago and other cities of more than 50,000 inhabitants by the Miles acid process (Weston, '16) in order to recover grease, ammonia, and glycerine, and to leave a strongly acid effluent which, in the case of Boston and other coast towns, would provide a sterile medium for oyster-beds, is a matter demanding very careful investigation, since acids $\left(\frac{M}{1000}\right)$ are fatal, or essentially so, to the eggs of such marine animals as have been tested with

them. Moore and others ('05), in experiments with acids and alkalies found that the addition of a very little acid checked or stopped development in sea-urchin's eggs, while much more alkali could be used without ill effects. This conclusion was confirmed by Whitley's experiments with the eggs of the plaice, one of the flatfishes. After using several acids and several alkalies Whitley concluded ('05) that the deleterious effect on these eggs was due to hydrogen and hydroxyl ions. The earlier work of Loeb ('98, '04) as well as that of Medes ('18) showed the same thing. For the relative toxicities of salts and acids see Table III; note that HCl is 404 times as toxic as common salt.

The addition of acid to water is accompanied by the liberation of CO_2. This may be released from carbonates in quantities very harmful to fishes. Methyl-orange acidity is nearly always fatal to them (Marsh, '07; Wells, '15). In all such cases the precise hydrogen ion concentration should be determined, but the concentration fatal to the various stages must not be neglected. Limestone is often used to neutralize acid, sometimes to doubtful advantage. Table III shows the relative toxicity of a number of different compounds in distilled water. The table is incomplete and based on the work of several authors. Further investigation is needed along this line.

TABLE III

Showing the relative toxicity, on a basis of weight, of different substances when added to distilled water, which was used except in the experiments marked (S). (KM) signifies according to Kahlenberg and Mehl, '01; (KH), according to Koenig and Hasenbaeumer, '02; (Ms), Marsh, '07; (M), Mathews, '04; (P), Powers, '18; (S) Shelford, '17; (W), Wells, '15a. The toxicities of sulfurous acid and its salts were calculated on the basis of the similarity of the resistance of some of the wild fishes and goldfish. The figures are only approximate for results by the same author. Comparisons between the results of different authors show some striking differences, but the great toxicity of acids and alkalies is evident. The higher the figure the greater the toxicity of the substance. All are compared with common salt, which is taken as 100 for all.

Animals tested	Poison		Chlorides (Cl)	Sulfates (SO_4)	Nitrates (NO_3)	Carbonates (CO_3)	Bicarbonates (HCO_3)	Hydroxides (OH)	Sulfites (SO_3)	Acid sulfites (HSO_3)
Fresh-water fishes	(Acids)	H	40,400 (KM)	15,000 (KM)	23,000 (KM)	3,700 (S)	.....	.....	11,700 (KH) 14,000 (S)†	
(Based on amount required to kill in 45 min. to 3 hours)	(Salts)	Na	100 (P)	.....	54 (P)					
		K	50 (P)							
		Ca	59 (P)	.....	118 (P)	.....	.....	15,000 (Ms*)	22,000 (KH)	10,000 (KH)
		Br	60 (P)							
		Mg	77 (P)	15 (KM)	105 (P)					
		NH_4	300 (S)	450 (S)	232 (P)					
			65 (P)	400 (W)	.....	.....	.....	30,000 (S)		
Marine Fundulus eggs	(Acids)	H	249,500 (M)							
(Based on least fatal dose)	(Salts)	Na	100 (M)	97 (M)	69 (M)	.....	138 (M)	14,610 (M)		
		K	70 (M)	.....	38 (M)	.....	.....	6,200 (M)		
		Ca	185 (M)							
		Ba	56 (M)	.....	.....	.....	.....	8,100 (M)		
		Mg	113 (M)							
		NH_4	88 (M)							
		Sr	53 (M)							

*Least fatal dose to trout; not comparable, but of right order of magnitude. †SO_2.

When these substances are introduced in water in which salts are already in solution the results are sometimes not in agreement with those obtained when the substances are in solution alone. CO_2 renders some salts less toxic. One salt often renders another less toxic or may neutralize its effect. On the other hand, combinations are sometimes more toxic than the individual constituents alone. Wells found that a little HCl reduced the toxicity of common salt to about one-third. Ammonia salts are harmless to some fishes in the absence of carbonates but toxic in their presence. This subject is too complicated and knowledge too meager to justify inferences as to the effect of mixtures of salts in streams. Organic compounds are often more toxic in the presence of salts. For data on this subject see Clowes, '17; Lillie, '12; Loeb, '06, '12; Osterhout, '14, '14a, '16; Powers, '18; and Spaeth, '17. Osterhout ('14a) has constructed important curves showing some of the most antagonistic mixtures of salts.

The toxicity of residuals of partial recovery may be determined directly if the process of treatment is in operation; if not, and if the character of the residuals is not known it is necessary to take a series of the representative constituents in a pure state, and to make tests of their toxicity. When this has been done it will usually be possible to foresee the toxicity of any residual of a proposed method of treatment (Shelford, '17).

Determination of Hydrogen Ion Concentration; that is, its Acidity or Alkalinity.—This is best done by indicators (McClendon, '16; Clark and Lubs, '17). The addition of substances to sea water demands some special attention, as precipitation of calcium and magnesium carbonates precedes any marked increase of hydroxyl ions due to the addition of alkalies (Whitley, '05; Haas, '16). They settle out as a white precipitate.

Treatment of Water during Low-water Stages.—Aeration of the effluent after considerable dilution will always help to render it less dangerous. Some of the aerating devices used in the activated-sludge process of sewage treatment will serve. (Porter, '17; Bartow, '17.)

V. Do animals turn back from the polluting substance and thus escape destruction; or do they swim into it and die?

Fresh-water fishes swim into nearly all coal-gas waste constituents, and on returning to clear water avoid it because intoxicated, and die. This fact of course increases many times the danger from these substances. Fishes often react in this way to SO_2, which may be a source of danger in the Miles acid process. The most important reactions of this kind are probably those of fish which run on shore. The great sensitiveness of herring in reactions to small quantities of CO_2 in sea water suggests that the erratic runs of this fish on our Pacific coast may be due to some such negative reaction. Likewise the great historical failure and alleged migration of the herring in Europe which contributed to the decline of the Baltic towns of the Hanseatic League and to the rise of Amsterdam may have been due to a similar cause.

The acids from munition works have attracted attention of late. An effluent composed of 0.13 to 0.4 per cent. of acid—a mixture of 2 parts of sulfuric acid and 1 part of nitric acid—is discharged by guncotton works. This acid effluent flowing into the brackish waters of the coast of New Jersey repelled the killifishes, on which the keeping down of mosquitoes depends. It was proposed to treat the acid effluent with lime, and the question of the effect of the calcium nitrate on the fishes became a problem for immediate solution.* Similar problems are arising in connection with inland rivers. Large quantities of such acid is now being run into the Sangamon River by munition works at Springfield, Ill., and into various other waters of this state.

The Gradient Tank.—The gradient tank in which experiments designed to answer question V are performed, should be twice as wide, three times as deep and twenty times as long as the length of the fishes to be tested (Shelford and Allee, '13; Powers, '14; Wells, '15). Where the density of the water introduced at the two ends is different inclined screens should be used (Shelford and Powers, '15, p. 327).

Temperature.—It is necessary to see that the temperature of the water at the two ends of the tank does not differ more than 0.2°C. (Wells, '14; Shelford and Powers, '15).

VI. Do polluting substances cover the bottom and make conditions unfavorable for eggs?

The majority of important fresh-water animals—mussels, which furnish pearl for buttons, whitefish, bass, sunfish, etc.—are dependent on the bottom for breeding, living conditions, or food. For example, bare clean terrigenous bottom is necessary as a resting-place for eggs of the whitefish of the Great Lakes (Clark, '10). It breeds in 8–25 meters of water. Many of the important breeding-grounds in the Great Lakes have been ruined, or at least rendered unusuable for a long time to come, by the accumulation of slowly putrescing sawdust, water-logged wood, etc. (Clark, '10). In Grand Traverse Bay, Lake Michigan, in 1871, salmon ova were discovered to be diseased and decaying, with particles of sawdust adhering to them (Milner, '74). Tarry material often covers bottoms and destroys life there. In the case of marine animals such as herring, clams, and mussels, similar serious results may occur.

Bottom-sampling.—The Petersen bottom-sampler is the best instrument to be used in deep water (Murray and Hjort, '12, p. 785). For shallow-water methods see Baker, '16. If the contaminating substances are covering breeding bottoms of bare sand and gravel they are dangerous (Knight, '03).

Bottom Index Organisms.—The presence of gilled snails of the genera Pleurocera and Goniobasis in fresh water indicates clean bottoms. Various other organisms usually indicate pollution with sewage (Forbes and Richardson, '13).

* For this information the writer is indebted to R. S. Patterson, of the New Jersey Mosquito Commission.

Bottom Oxygen and Carbon Dioxide.—Samples should be taken from the bottom. The oxygen content of water over breeding grounds should be about 4 c.c. per liter, and CO_2 probably not more than 1–5 c.c. per liter, the precise amount depending on the fish species present (Shelford, '14; Wells, '13, '15, '15a). The effect of CO_2 on the eggs of fresh-water fishes has not been fully determined (Ransom, '66). (Milner, '74; Anthony, '08; Paige, '08; Birge and Juday, '11; Shelford, '11, '11a, '11b; Forbes and Richardson, '13; Wells, '13.)

Conditions favoring Fungi.—It is probable that acidity, that is, much CO_2, and bad aeration favor fungus attack. Such attacks usually occur on eggs or adults; not on fry (Clinton, '93; Dean, '93; Richardson, '13).

VII. If the supply of useful animals is depleted will recovery be rapid or slow?

Petersen and Jensen found that if the flora and fauna were removed from marine bottoms useful animals such as oysters can not again live on them until a series or succession of plants and animals has prepared the way. (Petersen and Jensen, '11; Mőbius, '83.) The same is true of fishes in fresh water. A body of water deprived of all its vegetation, with the associated animals, requires much time for recovery. It is not simply the useful animals that must be taken into consideration, but the entire association (Adams, '09; Shelford, '10, '11, '11a, '11b).

VIII. Can correct decisions be reached without investigation of individual cases which arise?

Decisions relative to all the preceding points must usually be reached on the ground. Waters differ in their capacity to neutralize the effects of effluents, in the maximum and minimum flow, and in their dissolved content. Samples of water should be taken with reference to the particular animal-problem in hand. Carbon dioxide and oxygen determinations should be made on the ground, and at least a small amount of observation is indispensable. Mere office decisions, made at a distance and based upon report and inferences, are dangerous. The "antagonisms" of poisons, discussed on page 33, make decision without experiments unwise.

IX. What is the real value of the waste when the amount of the damage which it causes is added to its commercial value?

One continually hears it said that the recovery of this or that waste product does not pay; that this is an all-sufficient reason for not recovering it—and the matter is usually dismissed forthwith. We need an entirely new view-point. The value of any waste product is its commercial value, when properly recovered, plus the amount of loss it occasions when unrecovered. Practically all kinds of waste may be made into something useful (Koller, '15; Weston, '16; Feilding, '17). The recovery of grease from sewage or garbage might not pay under market conditions, but if the grease so recovered will prevent the national supply from giving out it should be recovered by all means. It has been esti-

mated (see *Oil, Paint and Drug Reporter*, '18 and '18a) that the sewage of ninety-seven cities of more than 50,000 inhabitants, treated by the Miles acid process, would yield per year as follows:

Fertilizer	97,393,680 tons
Ammonia	4,869,684 tons
Grease	25,780,680 tons
Glycerine	1,289,039 tons

Recovery plants have not been installed, however, because critics of the conservation plan maintain that the profits will be less than its friends have predicted. As has been true in most other cases, calculations of the cost of suitable recovery plants and of the value of recovered products have been made with only minor regard to public health, and with little reference to the damage which the remaining effluent may do to fishes. In correct calculations the value of the recovered products and the benefits to public health would both be regarded as credits. The dangers or benefits to fisheries from the residual acid effluent of the Miles process should also be considered. This effluent is 50 parts per million acid. Either sulfuric acid or sulfur dioxide may be used in the process. Sulfur dioxide and salts of sulfurous acid (Phelps, '09) are probably more toxic to fishes than sulfuric acid and its salts (see Table III). The acid should be neutralized if present in dangerous concentrations, and the cost of reducing the acidity of the effluent balanced against fisheries protected thereby.

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ARTICLE III.—*A New North American Oligochaete of the Genus Haplotaxis.** BY FRANK SMITH.

INTRODUCTION

The only papers describing North American Haplotaxidae are two by Forbes ('90 and '90a) in which he describes *Haplotaxis emissarius* from Illinois under the name *Phreoryctes emissarius*. The present paper extends the original description by giving the positions of the gonads and spermathecae, hitherto unreported. It also includes the description of a new species, *Haplotaxis forbesi*, from the Illinois River.

Forbes found no trace of reproductive organs in his specimens. The following quotation ('90a : 108) indicates what he regarded as the important characters in which *H. emissarius* differed from *H. menkeanus*, the closely allied European congener: "It differs especially by the fact that the dorsal rows of setae are obsolete except on a variable number of the anterior segments and that the lateral vascular arches extend from the dorsal to the ventral vessel, instead of connecting only with the latter." Later, Michaelsen ('99) gave reasons for believing that faulty observations by earlier European investigators were responsible for these reported differences, and that the European species actually corresponded with the description of Forbes in the absence of dorsal setae from most of the somites, and in the relation of the commissural blood-vessels. At this time Michaelsen considered that the various known forms of Haplotaxis of the northern hemisphere all belonged to one variable species, *H. gordioides* (Hartmann). In a later paper ('05) he described another species, *H. ascaridoides*, from Lake Baikal, in Siberia, which differs chiefly in the number of spermathecae present in sexually mature specimens, there being four pairs in the latter species and but three pairs in *H. gordioides*. Since the immature specimens of the two species are extremely similar, and since only immature specimens of the North American *H. emissarius* were known, Michaelsen concluded ('05 : 67) that the assumption that the latter species is identical with *H. gordioides* is not justifiable without a comparison of the reproductive organs.

REPRODUCTIVE ORGANS IN HAPLOTAXIS EMISSARIUS (Forbes)

Through the kindness of Professor Forbes I have had the privilege of examining the series of sections on which his description was partly based. I find vestiges of four pairs of gonads in 10–13. Two specimens in my own collection, from the same region (Champaign, Illinois) and from the same kinds of situations (tile drains) as were the type

* Contributions from the Zoological Laboratory of the University of Illinois, No. 118.

specimens of *H. emissarius,* apparently belong to that species. These specimens have better developed gonads, and they are clearly in 10–13* (Pl. II, Fig. 4). One of the specimens has also three pairs of organs that are almost certainly degenerating spermathecae. They are in the anterior parts of 7–9 (Pl. II, Fig. 4), and open in 6/7–8/9 at the level of the lateral line of either side. Since the number and positions of the gonads and of the spermathecae in *H. emissarius* are the same as in *H. gordioides,* the actual status of the former must remain undetermined until still more can be learned about the reproductive system. We have no information concerning the sperm ducts, oviducts, sperm sacs, or ovisacs. These may easily furnish distinctive specific characters.

A New Species from the Illinois River

In 1894 and 1895, while in service for the Illinois State Laboratory of Natural History at the Biological Station on the Illinois River, the writer found many specimens of a Haplotaxis species in the wet banks of the river near Havana, Illinois, and preserved a considerable number, assuming that they were *H. emissarius* and that their reproductive organs might be sufficiently developed for description. Several series of sections were made, but a preliminary study showed that the specimens were not sexually mature, and as an anomalous relation of the gonads was apparent it seemed advisable to wait for better developed specimens. During the interval of over twenty years the desired specimens have not been obtained, and a recent study of the material at hand has led to the unexpected discovery that the Illinois River worms belong to a species distinct from *H. emissarius.*

Haplotaxis forbesi, sp. nov.

Length, 100–150 mm. Diameter, 0.6–0.7 mm. Somites, 260–284. Prostomium approximately twice as long as wide. Setae, two to four per somite; dorsal setae much the smaller and limited to a few anterior somites. Gizzard in part of 4–5. Nephridia large in 12–14 and posterior to 17. Spermaries: one pair, in 10. Ovaries paired; in 15 and 16.

Cotypes, in the collection of the Illinois State Laboratory of Natural History (Accessions Cat. Nos. 27136 and 27137), and in the collection of the writer. Named for Professor S. A. Forbes, who first made known the presence of Haplotaxidae in North America.

But few of the specimens were preserved entire. Only the anterior 30 or 40 somites were saved in the case of most specimens, since short pieces were much more easily prepared for sectioning. Transverse, sagittal, and frontal sections of eight anterior ends, and cleared specimens of nine other anterior ends were used in the study of the more important characters.

External Characters

The measurements given above—length, 100–150 mm., and diameter, 0.6–0.7 mm.—are based on alcoholic material. The number of somites

* Arabic numerals are used to designate the somites.

in apparently complete specimens is somewhat less than 300. The prostomium is without terminal pore and in some specimens transverse grooves are evident. Its length anterior to the mouth is nearly twice its width and equals the distance from the mouth to the middle or end of the fourth somite. The first five somites are shorter and broader than those next following and give the impression of a slight degree of cephalization, which is also manifest in the internal structure (Pl. II, Fig. 7). A distinct groove which seems, on the dorsal and lateral walls, to define clearly the anterior border of the first somite makes that somite appear slightly longer than the second, and apparently locates the mouth-opening on the mid-ventral surface of the somite rather than at its anterior margin. This leaves but a short interval between the mouth and the intersegmental groove 1/2. If a similar state of things exists in other species it may account for the apparent extreme shortness of the first somite which has often been mentioned. I find a similar condition in *H. emissarius*.

The ventral setae (Pl. II, Fig. 6) are of the ordinary haplotaxid type, with nearly straight inner shaft, slightly developed nodule at about one-third of the length of the seta from the distal end, and distal part strongly curved. Ordinary measurements are 0.30–0.32 × 0.022 mm. The dorsal setae are very much smaller (0.125 × 0.007 mm.), begin quite uniformly on the fifth somite, and are present on only the next following 12–20 somites. This character is presumably not of much systematic importance but is fairly uniform in a considerable number of specimens. The setal distances are approximately indicated by the following formula in which *l* represents the lateral line: $aa : al : ld : dd = 4 : 4 : 3 : 8$. No clitellum nor genital papillae have been found.

INTERNAL CHARACTERS

The buccal region (Benham, '04 : 301) is thin-walled and connected to the body wall by numerous muscular strands, and extends through the first three somites. The gizzard has its chief development in the posterior part of the fourth, and the anterior part of the fifth, somite, where the muscular wall is strongly thickened. The vascular system much resembles that already described for other species. The dorsal vessel forks just posterior to the brain. The branches extend anteriorly and then posteriorly and, after a somewhat tortuous course, unite in the posterior part of the third somite and form the anterior part of the ventral vessel. One pair of slender commissural vessels in each of the setigerous somites connects the dorsal and ventral vessels. The connections posterior to somite 4 are in the posterior part of the somites, close to the septa. The connections of the vessels of each of somites 2–4 are in the anterior part of the following somite.

The distribution of the nephridia differs from that usually found in the genus, the peculiarities of arrangement being correlated with those of the reproductive organs, to be described later. Ordinary nephridia like those described in other species of the genus are found in 12–14 and

in 18 and the following somites (Pl. II, Fig. 3). One specimen has a large nephridium on one side of 9, and a few have fairly large nephridia in 15 and 16. They are regularly much smaller or absent in 10, 11, and 17, and in some specimens in 15 and 16.

The brain differs somewhat in shape from that of *H. emissarius* and certain other species. The length of the median antero-posterior axis is about equal to the greatest lateral diameter (Pl. II, Fig. 1), and the greatest dorso-ventral axis is about three-fourths as great. The posterior surface is but slightly concave, and the anterior surface is conical with the apex somewhat rounded. In median frontal sections of the brain, the anterior margins include an angle of about 90°. The peculiar cushions of cells which support the ventral nerve cord are, as far as observed, found associated with all the ganglia except the first one. Those related to the second and third ganglia, in somites 3 and 4, are small and without the lateral wing-like extensions, and the others are larger and have such extensions more or less developed. No examination has been made of their distribution in the posterior part of the worms.

The reproductive organs are but incompletely developed in all of the specimens examined, but the gonads are large and unmistakable. Eight sectioned specimens and nine specimens cleared in cedar oil are perfectly uniform in having one pair of gonads in 10 and one pair in each of somites 15 and 16 (Pl. II, Fig. 3). The anterior pair are doubtless spermaries and the other two pairs are ovaries. There are vestiges of spermiducal funnels and of the adjacent parts of the sperm ducts, but no traces of the location of the spermiducal pores. Two sectioned specimens show sufficient vestiges of the oviducal apparatus to indicate that the oviducal pores were in the anterior parts of 16 and 17 and dorso-laterad of the lines connecting the ventral setae of either side of the worm. One of the two specimens has an additional ovary of small size on one side of 17 but has no corresponding oviduct. The wide separation of the ovaries from the spermaries and the extreme posterior position of the former are characters that are very aberrant, not only for the genus, but for the Oligochaeta as a whole. No traces of sperm sacs, ovisacs, or spermathecae have been detected.

General Discussion

The marked differences in the relations of the gonads are sufficient to distinguish *H. forbesi* from *H. emissarius,* but it differs also in its smaller size; in the small number of somites in apparently complete worms; and in having fewer somites with dorsal setae. The shape of the brain also is quite different in the two species (Pl. II, Fig. 1 and 2), as shown by a comparison of the following three measurements: median antero-posterior axis, greatest lateral diameter, and greatest dorso-ventral axis. These ratios for *H. forbesi,* in the order mentioned, are 4 : 4 : 3; and those for *H. emissarius,* 5 : 8 : 4.

The scanty records of the occurrence of *H. forbesi* give almost no information concerning its distribution or the precise kinds of situations

in which it is to be found at different times of the year. The records are confined to 1894 and 1895, when careful periodical surveys were made of the plant and animal life of the Illinois River and its connected lakes at the Biological Station. Although there were numerous dredging operations at different places in the river channel, the only specimen taken in this way was obtained December 18, 1894, at Station E, directly opposite a place on the shore where all our other specimens of *H. forbesi* were taken. In May, 1894, numerous specimens were found on both sides of the river at Station E, in the water-soaked banks, just above the water level. In the interval between April 13 and 23, 1895, numerous specimens were found at the same station, but in the west bank of the river only. Their abundance is indicated by a memorandum stating that 29 specimens were taken from the mud obtained by an assistant by three successive scoops with the hands. At this time a careful search was made for specimens in other locations at various places down the river for nearly six miles, but none were found.

Apparently they are nearer to the surface in April or May than at other times of the year. Just where they are during the remainder of the year is entirely unknown. Since *H. emissarius* is subterranean in habit, being collected chiefly from wells and tile drains, it seems reasonable to suppose that the new form also may have a subterranean habitat during most of the year.

The time of sexual activity of *H. forbesi* is unknown. The specimens collected are all of about the same stage of development, with gonads quite large and often extending nearly to the posterior septum, but without any signs of cell-division activity. We have no records of partially grown, juvenile specimens.

It seems probable that both *H. emissarius* and *H. forbesi,* and perhaps other species of the genus, actually occur in many parts of North America, but have thus far escaped notice except in Illinois.

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PLATE II

Fig. 1. *Haplotaxis forbesi*, frontal section through prostomium and brain in plane of longest antero-posterior axis of latter. × 105.

Fig. 2. *Haplotaxis emissarius*, same as above.

Fig. 3. *Haplotaxis forbesi*, diagram showing location of gonads, ducts, and nephridia (of left side). (Double lines indicate large normally developed nephridia, and single lines are in somites in which nephridia are imperfectly developed, or sometimes absent.)

Fig. 4. *Haplotaxis emissarius*, diagram showing location of gonads, spermathecae, and nephridia (of left side). (Double and single lines for nephridia are used, as in Fig. 3.)

Fig. 5. *Haplotaxis forbesi*, dorsal seta. × 175.

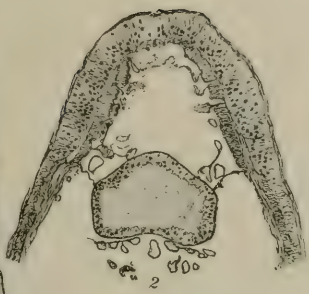
Fig. 6. The same, ventral seta. × 175.

Fig. 7. The same, longitudinal section through five anterior somites in a plane slightly oblique to the median sagittal plane and laterad of the same. The distal ends of ventral setae, the relation of the mouth to the first somite, and part of the musculature of the alimentary tract are shown. × 70.

October 1, 1918.

PLATE II

1



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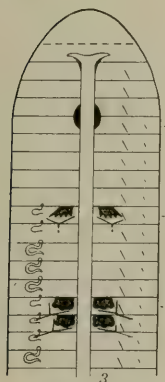

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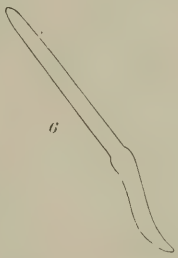

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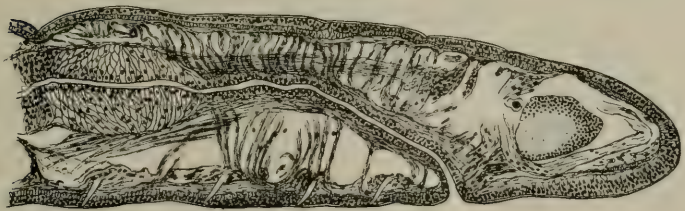

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ARTICLE IV.—*A Representative of the Genus Trichodrilus from Illinois.** BY JAMES E. KINDRED.

INTRODUCTION

The description given in this paper is based upon the detailed examination of a single specimen which was pumped from a well in Concord, Illinois, June 18, 1915. It was submitted to Professor Frank Smith, of the University of Illinois, with a question as to its harmfulness, and after this had been answered, was set aside. The specimen is now in the collection of Professor Smith, to whom I am under obligations for the opportunity to study it and for suggestions in the preparation of this report. It came into my hands mounted in cedar oil, in good condition for external examination, but the sections which were made for examination of the internal characters were unfortunately wrinkled in some of the most important parts of the reproductive somites, so that conclusive evidence for the presence or absence of certain of the reproductive parts can not be given, and therefore its exact status can not be established.

The resemblance of this form to the members of the European genus Trichodrilus Claparède is evident, and many points in its anatomy link it with the type species of the genus, *T. allobrogum* Claparède. No representative of this genus of the Lumbriculidae has as yet been recorded in North America, and still other representatives may exist in the kind of environment in which the present worm was found. Any small aquatic worms which are pumped from our wells from time to time may be important in extending our knowledge of Trichodrilus and other genera of the oligochaete fauna of the United States. It is desirable that persons finding such forms should send them to qualified specialists for identification if they can not themselves determine them with the aid of the brief description of the species of Trichodrilus given at the conclusion of this paper, thus aiding in the settlement of the position of doubtful forms and making known the presence of others, if there are such.

Besides *T. allobrogum*, two other species of Trichodrilus have been described from Europe, *T. pragensis* Vejdovský and *T. sanguineus* (Bretscher). The latter was first described as the type of a new genus, Bichaeta (Bretscher, '00), but Piguet ('13) placed it in the genus Trichodrilus. In the following section the details of structure of the Illinois form are given as far as the material will permit. Since it seems to

* Contributions from the Zoological Laboratory of the University of Illinois, No. 119.

be more closely related to *T. allobrogum* than to the other species, it is recorded under that name, with a query indicating the uncertainty of its position.

Trichodrilus allobrogum Claparède (?)

EXTERNAL CHARACTERS

The natural color of the worm seems not to have been noted, but the body wall was presumably unpigmented. It is 45 mm. long and its diameter in 10 is 0.54 mm. Anterior to 10, the body tapers gradually to a diameter of 0.33 mm. The prostomium appears to be elongate, but as it was doubled upon itself, it could not be measured. There are 116 somites in the specimen, which has evidently lost several somites from the posterior end. Each somite has an annulation dividing it into a narrower anterior part and a wider posterior one, the latter bearing the setae. The setae are slender, elongate, nodulated, and sigmoid. A dorsal seta from 10 is 0.175 mm. long, 0.003 mm. in diameter at the base, and 0.007 mm. in diameter at the nodule, which is at a distance of 0.061 mm. from the tip. The clitellum is indistinct, although the worm was in a sexually active condition at the time of fixation.

The spermiducal pores are borne at the distal ends of a pair of genital papillae which are on the ventral surface of 10, just posterior to the ventral setae. The oviducal pores are in the intersegmental groove 11/12, in line with the ventral setae. There are two pairs of spermathecal pores, one of which is on 11, between the ventral setae and the oviducal pores, and the other in 12/13, in line with the ventral setae.

INTERNAL CHARACTERS

The pharynx is thick-walled and extends into 6. In 4 it is 0.043 mm. in diameter, while the diameter of its lumen is 0.017 mm. It is covered with large deeply staining glandular cells, the septal gland cells, from 4 to 6. There is no distinct line of division between the esophagus and pharynx. The chloragogue cells begin in 7. The structure and relations of the circulatory system and of the nephridia are not sufficiently clear to be of value in comparisons.

There are two pairs of spermaries attached to the septa 8/9 and 9/10 respectively, and projecting freely into 9 and 10. These two somites are filled with developing spermatozoa unenclosed in sperm sacs, but there is a small median sperm-sac projecting anteriorly into 8, and either one or two sacs filling up most of 11 and 12. The spermatozoa in these somites are distinctly enclosed in walls which are somewhat twisted and do not permit of a satisfactory determination as to the number of sperm sacs.

Only one pair of spermiducal funnels could be located, and these are on the anterior face of 9/10. The presence or absence of a posterior pair can not be ascertained because of the folding of the sections in the region where they would be most likely to occur, but they are probably present. On each side a narrow sperm-duct, measuring 0.014 mm. in diameter with a lumen 0.003 mm. in diameter, extends posteriorly from

the spermiducal funnel of 9 to the atrium. It is unconvoluted in its passage along the floor of 10 and curves dorsally to enter the atrium in this somite. Columnar cells like those which make up the wall of the sperm duct line the lumen of the atrium, which is about three times as great in diameter as the lumen of the sperm duct. In addition to the epithelium of the lumen, the wall of the atrium of either side has a layer of muscle which is in turn surrounded by a mass of small glandular cells. A layer of circular muscle-fibres, continuous with the layer beneath the epidermis of the genital papilla, is present around the distal end of the atrium between the epithelial and longitudinal muscle-layers. This layer is folded in such a manner as to suggest that this part of the reproductive apparatus may be an eversible penial organ.

The ovaries are on the posterior face of 10/11 and project freely into 11. The oviducal funnels are on the anterior face of 11/12. There are two pairs of spermathecae, one pair each in 11 and 12. These are very large and not exactly uniform in shape, although this lack of uniformity is presumably due to their treatment after fixation. The one on the right side of 11 is almost spherical and is 0.142 mm. in diameter, the wall being composed of flattened squamous epithelium, 0.007 mm. thick. The duct leads directly to the exterior from the posterior surface of the ampulla, and its cells are more columnar in character than those in the wall of the latter. The length of the duct is 0.170 mm.; the diameter, 0.038 mm.; and the diameter of its lumen, 0.011 mm. There is no sign of the degeneration or disappearance of these organs. The other three spermathecae are more ovoid than the one described, but all are approximately of the same size, and their ducts have the same general relations to the ampullae.

The following brief diagnoses of the three European species of Trichodrilus have been appended for the benefit of readers who may be interested in the identification of these aquatic worms but do not have access to the scattered literature concerning them.

Trichodrilus allobrogum Claparède

Length, 20–25 mm. Somites, about 70. Color, yellow. Prostomium conical, about twice as long as diameter of base. Clitellum indistinct. Nephridiopores in line with ventral setae. Spermiducal pores on 10, on pair of genital papillae, posterior to ventral setae. Oviducal pores in 11/12. Spermathecal pores: one pair on 11 between oviducal pores and ventral setae; one pair on 12 in line with ventral setae. Setae simple-pointed, sigmoid, nodulated, two per bundle. Five or six pairs of transverse vessels per somite (one pair blind and contractile). Nephridia in 7 and 8; lacking in 9–12. Spermiducal funnels: a pair on the anterior faces of 9/10 and 10/11 respectively. Sperm ducts from these open into a pair of common atria in 10. Atrium pear-shaped, covered with glandular cells, with eversible penis at distal end. Spermaries.—? Ovaries in 11. Oviducts and funnels on 11/12. Spermathecae ovoid; long narrow duct to exterior; a pair in 11 and 12 respectively.

Trichodrilus pragensis Vejdovský

Length, 30–40 mm. Diameter, 0.6–0.7 mm. Somites, 60–80. Color, reddish white. Prostomium rounded, about twice as long as diameter at base. Clitellum indistinct. Spermiducal pores on 10, posterior to ventral setae. Oviducal pores in 11/12. Spermathecal pores: one pair on 11 between the oviducal pores and ventral setae; one pair on 12 in line with ventral setae. Setae simple-pointed, sigmoid, nodulated, two per bundle. Eight pairs of transverse vessels in anterior somites. Dorsal vessel with 4–6 asymmetrically arranged caecal diverticulae per somite, with forked tips. Nephridia in 8, 14, 22, etc., irregularly distributed, and extending into other somites. Spermiducal funnels paired in 9 and 10. Sperm ducts opening into a pair of atria in 10. Atria as in *T. allobrogum*. Spermathecae arranged as in *T. allobrogum,* but the second pair disappears in sexually active worms.

Trichodrilus sanguineus (Bretscher)

Length, 9–13 mm. Somites, 50–72. Differs from *T. pragensis* chiefly in having bifid setae. Spermathecae of 12 disappear in sexually active specimens as in *T. pragensis*. Lateral branches of dorsal vessel not described.

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ARTICLE V.—*Contributions to a Knowledge of the Natural Enemies of Phyllophaga.** BY JOHN J. DAVIS, Entomological Assistant, Cereal and Forage Crop Insect Investigation, Bureau of Entomology, U. S. Department of Agriculture.

INTRODUCTION

On account of the difficulty of controlling the common white-grubs, which pass ninety-five per cent. of their life under ground, their natural enemies are of unusual importance to the farmer. No one species of animal can be regarded as the most important check on the increase of the grub, but of its insect enemies the black digger-wasps belonging to the genus Tiphia are undoubtedly the most generally common and wide-spread, and are among the most effective insect parasites of white-grubs. In some sections the yellow-banded digger-wasps of the genus Elis are abundant, and in others asilid larvae of one species or another are of considerable importance. Two-winged flies of the ortalid genus Pyrgota and others of the family Tachinidae parasitize the beetles, are generally distributed, and serve as significant checks. Among the native mammals and birds the skunk and crow stand out as models of efficiency in grub eradication. Diseases of various kinds are effective sporadically, but their occurrence is too infrequent, too local, and too dependent on weather conditions to make them as generally useful and reliable as the insects, mammals, and birds mentioned above.

The efficiency of certain of the enemies of the white-grubs has been repeatedly demonstrated. During 1915 a nematode disease became evident in some sections, and heavily infested fields were practically freed of white-grubs by the action of this parasite. In another section, during the same year, a protozoan disease eradicated the pest in some fields. The black digger-wasps have undoubtedly controlled the grub in some sections where the pest once wrought havoc to corn crops. Adversely, the destruction of wild game, including birds and mammals, is apparently responsible in part for the increasing abundance of such destructive pests as white-grubs. These insects are seldom so injurious or wide-spread as were the destructive broods of 1912 and 1915, and their superabundance at any given time or place is apparently due to a decrease in the natural enemies which under ordinary conditions would keep them under reasonable control.

The value attached to their natural enemies in the control of the white-grubs is well shown by the fact that the Porto Rican sugar-growers

* The specific synonymy of this genus here adopted is that given by Glasgow in his revision of the synonymy of the genus Phyllophaga Harris (Lachnosterna Hope)—Bul. Ill. State Lab. Nat. Hist., Vol. 11, Art. 5, Feb., 1916.

have had an expert traveling throughout the United States for several years gathering parasites for use in the control of the white-grubs in Porto Rico, where they are very injurious to sugar-cane and other crops.

The object of this paper is to place on record our preliminary observations, to bring together the complete records of white-grub enemies for the use of others in this work, and to stimulate the study of the beneficial species occurring in different localities. The writer is especially anxious to receive living parasites from all sections of the country, and persons able and willing to cooperate are requested to notify us of that fact.

The writer is especially grateful to Messrs. W. R. Walton and H. E. Smith and Dr. J. M. Aldrich, who determined most of the dipterous parasites, and to Mr. A. B. Gahan for the determination of the Hymenoptera. Thanks are due the various state and bureau officials mentioned hereafter in the text, who have furnished specimens used in our work. We also take this opportunity of expressing our appreciation of the cooperation and assistance of colleagues who have served at the Lafayette Laboratory from time to time, including Philip Luginbill, C. W. Creel, W. J. Phillips, R. J. Kewley, A. F. Satterthwait, H. J. Hart, F. A. Fenton, S. L. Mason, H. Fox, D. G. Tower, and D. A. Ricker. Photographs for figures 8, 10, 12, 28, 30, 31, 41, and 42 of the plates were taken by Mr. J. H. Paine; and the excellent drawings for the text illustrations were, with a few exceptions, made by Miss E. H. Hart and Mr. W. R. Walton, of the U. S. Bureau of Entomology, for which the writer expresses grateful acknowledgment. The writer is further indebted to his brother, H. A. Davis, for the lettering of charts I and II.

To Dr. S. A. Forbes, the writer wishes to express his gratitude for the inspiration and encouragement received when as a member of the staff of the State Entomologist's office he first attempted studies on white-grub enemies, and for the opportunity afforded for the publication of this paper.

Ecological Considerations

Although this paper is intended primarily to present the known facts relative to the individual enemies of Phyllophaga, it seems desirable briefly to note some of the relations existing between the many parasites, hyperparasites, and predators, and their hosts. The two accompanying charts present these facts graphically and require but few words of explanation.

Chart I shows in a concise form the enemies of Phyllophaga from egg to adult.

Chart II is a diagramatic illustration of the relations existing between Phyllophaga and its enemies, but does not take into consideration the interrelations of Phyllophaga and other beetles such as Cotalpa, Cyclocephala, and Ligyrus, which are attacked by some of the same enemies, since this would complicate and confuse the diagram.

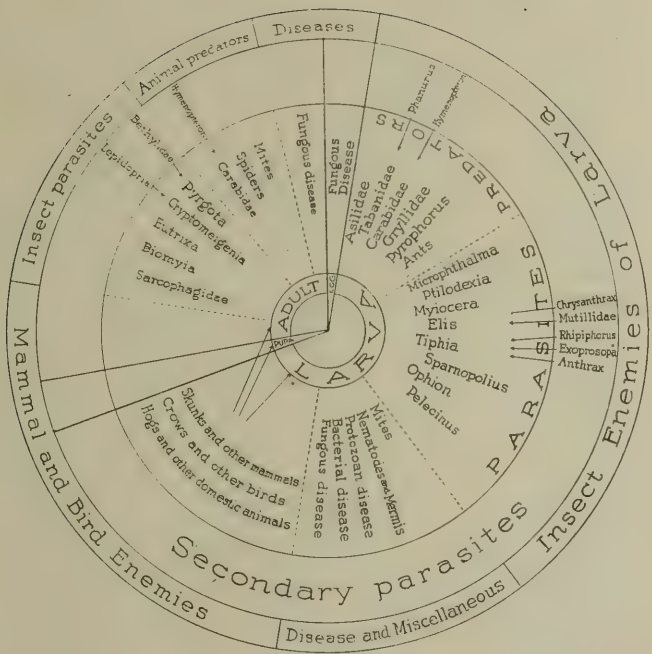

CHART I. Concise exhibit of the enemies of egg, larva, pupa, and adult of Phyllophaga.

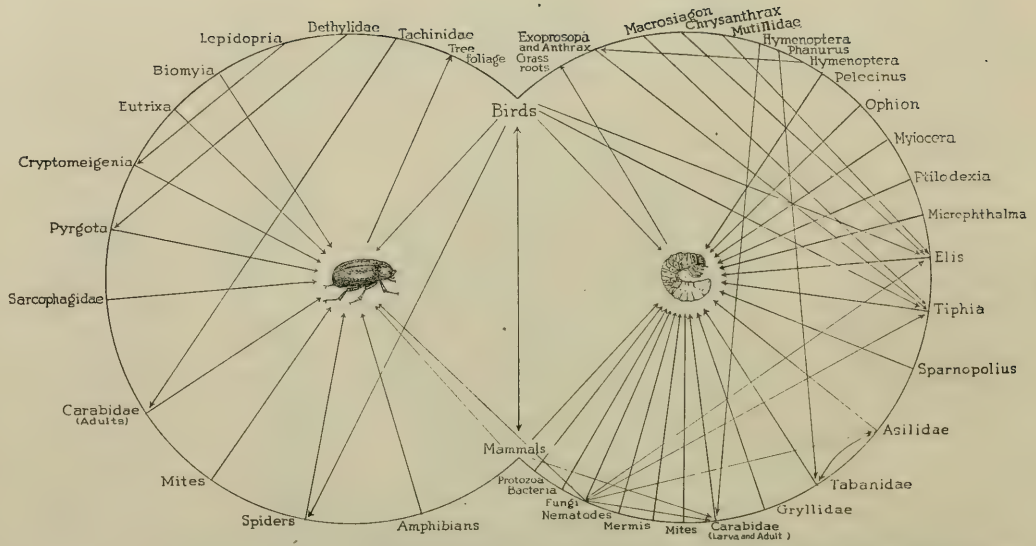

CHART II. Diagram showing interrelations of Phyllophaga and its enemies. The arrows point towards the food-plant, host, or prey of parasite or predator.

It will be noticed that the length of the various stages of the host has a direct relation to the number of enemies in each stage. The egg and pupa each exist as such only about one month and, in addition, are well protected in their earthen cells, hence we find but few natural enemies affecting them. On the other hand, the larva, which exists for a much longer period, is beset with enemies, among the most important of which are digger-wasps belonging to the genera Tiphia and Elis, which are thoroughly adapted to burrowing through the soil in search of their host. These parasites have undoubtedly been responsible for the practical eradication of grubs in ceratin areas—sometimes rather restricted, which can be accounted for by the fact that Tiphia at least, on account of its large body and comparatively small wings, is unable to fly any great distance. Likewise, Tiphia, as well as all other white-grub parasites, is somewhat checked in its increase by the length of its life cycle as compared with that of Phyllophaga, the parasite having a one-year, and the host, as a general rule, a three-year, cycle, and although grubs of a particular size are present each year there is seldom more than one destructive brood; that is, an abundance of a grub of a particular size occurs only every three years, and although the digger-wasp parasites may become very abundant one year they are likely to decrease in numbers the following year on account of lack of host material. Another important detrimental influence affecting these wasps is plowing, which exposes the cocoon to heat and drouth in summer, to the cold of winter, and to the attacks of predaceous mammals and birds.

The adult dipterous flies of the genera Microphthalma and Ptilodexia are not adapted to enter the soil in search of their prey as is Tiphia, and must therefore deposit their young in cracks and crevices of the earth, the larvae being obliged to search for the grubs of their host insect; hence it appears that these species are more abundant in sandy and porous soils which offer the least resistance to a search for the grubs. Whether the flies are able to locate infested areas and thus deposit their progeny in favorable locations is not known, but it seems likely that this is the case. The hymenopterous enemies of the genera Pelecinus and Ophion, and the Diptera belonging to the bombyliid genus Sparnopolius are so rarely encountered that they are of no appreciable importance in their influence on the grub population. The beetles of the family Carabidae and their larvae are naturally predaceous and live in or on the surface of the soil, being always alert in their search for soft-bodied prey. Soil-inhabiting asilid and tabanid larvae are likewise generally predaceous, but the Asilidae are much the more important as white-grub enemies because they inhabit upland soils which are favorable to the development of most Phyllophaga species, while the Tabanidae are typically low-ground and marsh-inhabiting insects. Likewise we have in the Asilidae a most interesting example of a life cycle conforming to that of Phyllophaga; at least it appears that two species of Promachus have a three-year cycle as does the host, and, furthermore, they are able to live for long periods without food—an adaptation of

the greatest importance when we reflect that the larvae must forage, and apparently blindly, through the soil in search of grubs which may be few and far between. The Asilidae are also more or less beneficial in the adult stage as predaceous on other insects, though not attacking May-beetles since the former are diurnal and the latter nocturnal in habit of flight. On the other hand, the adult Tabanidae, or horse-flies, are well-known stock pests. The various nematodes and the protozoan, bacterial, and fungous diseases of Phyllophaga are but little understood. None of these agencies are known to be consistent checks on the multiplication of white-grubs, but occasionally one or the other of them appears in such force as to wipe out the entire white-grub population in some areas. Favorable climatic conditions and abundance of the grubs are the two most important factors promoting the appearance of the diseases; and, unfortunately, these conditions can not be duplicated in the field by artificial means, and they occur too rarely to act as reliable checks. The fungous diseases also affect the insect parasites of white-grubs.

The various native mammals and birds are among our most dependable friends, especially such animals as the skunk and such birds as the crows and robins, which seem instinctively to scent the grubs and May-beetles and search the soil for them. Many of the other animal predators, especially birds, are dependent on the plow to turn up the grubs.

Undoubtedly the increase in white-grubs in certain sections of the country is due largely, if not wholly, to the destruction of the wild mammals and birds which in years past prevented such insects from increasing to abnormal abundance.

Respecting the insect parasites of the adult May-beetles, it should be noted that all excepting the sarcophagids, most of which are probably not true parasites, are nocturnal in habit as is their host. Most May-beetle species are entirely nocturnal, feeding on the foliage of trees at night and hiding beneath rubbish or in the soil by day. The tachinid parasites of the adult deposit their eggs on the beetles while the latter are quietly feeding or copulating and are least likely to be disturbed; but the ortalid flies of the genus Pyrgota attack the beetles in flight. The Pyrgota species deposit their eggs in the bodies of the May-beetles, the opening of whose elytra in flight exposes the only part of the body soft enough to be pierced by the ovipositor of the parasite. A few sarcophagids may be regarded with reasonable certainty as May-beetle parasites, and it is interesting to note that they have been reared only from *P. lanceolata* and *P. cribrosa,* which are day-flying species, as are these parasites.

When we further reflect that these enemies are likewise attacked by parasites, that some birds and mammals which destroy Phyllophaga may also destroy the beneficial parasites, that the adult of one predaceous larva may prey on the adult of a similar predaceous larva, and that the

predaceous larvae likewise may attack one another, we begin to realize the immense complexity of the interrelations of these animals.

These few remarks indicate the importance of studying more thoroughly the interrelations of insect pests and their enemies, and especially the effects of varying conditions on each—problems which are practically untouched, and yet offer possibilities of the greatest economic importance.

Parasites of the larva

The Black Digger-wasps (Tiphia spp.*)

The black digger-wasps are without doubt the most efficient and abundant of the many parasites known to attack Phyllophaga. One or another of the species of Tiphia parasitic on our common white-grubs (Phyllophaga spp.) is to be found in greater or less abundance in every section of the United State east of the Rocky Mountains.

The adult wasps feed on the nectar of various roadside flowers, but much of their life is spent in the soil and therefore they are not frequently encountered. However, the rather common occurrence of their tan-colored, woolly, egg-shaped cocoons in the soil, to be seen in following the plow in almost any section of the country, is sufficient proof of the beneficial activity of these wasps.

The black digger-wasps were first recognized as parasitic, or more strictly speaking ectoparasitic, on white-grubs of the genus Phyllophaga by Riley, who in 1874 published an account of the habits and life history of a species which he referred to Say's *Tiphia inornata* (59).† Few additional facts were learned until 1907, when Forbes published an account (26) materially increasing our knowledge. Up to the present time, however, several species attacking white-grubs have been confused and practically nothing has been known of the different kinds. From our breeding records four species are now known to attack Phyllophaga larvae in the United States, each depositing its eggs on a different part of the grub, and several other species are parasitic on related grubs, such as Anomala, Ligyrus, Cyclocephala, Dyscinetus, etc. A fifth species (*T. parallela* Smith) is a parasite of the grub *Phytalis smithii*—a grub very much like our Phyllophaga—in the British West Indies, and, according to Nowell (53), the egg of this wasp is laid in a position identical with that of the egg of *T. punctata* on the Phyllophaga grub.

T. punctata Rob., our commonest species, lays its egg on the dorsum of the thorax of the grub—or on the first or second abdominal segment—usually on the second or third thoracic segment, just to one side of the median line, in a groove of the folds of the skin; *T. inornata* Say commonly lays its egg on the under side of the thorax, usually between the legs, but occasionally beneath the first abdominal segment; *T. transversa* Say lays its egg on the under side of the abdomen, usually on the fourth

* Determined by Mr. A. B. Gahan, and afterward checked up by Gahan using a key prepared by Mr. J. R. Malloch

† Numbers in parentheses refer to literature citations.

or fifth segment; and *T. vulgaris* Rob. is supposed to oviposit on the dorsum of the abdomen. In all cases the eggs are laid transversely and securely glued to the integument of the grub. It is interesting to recall in this connection some observations made by the writer in Illinois in 1907 while working under the direction of Dr. S. A. Forbes. The position of Tiphia eggs and larvae on grubs was noted in many cases while grubs were being collected behind the plow, and in every case, in spring and early summer, the eggs or larvae were found on the under side of the thorax and between the legs of the white-grub and may have been those of *Tiphia inornata*. In fall, on the other hand—that is during September and October—of the 63 eggs and larvae of Tiphia observed, 28 (probably *T. vulgaris*) were on the dorsal surface of the abdomen near the anal end; 24 (probably *T. punctata*) on the dorsum of the thorax; and 1 (probably *T. inornata*) was on the under side of the thorax.

The time of appearance of the wasps differs with the species, *T. punctata* and *T. transversa* appearing relatively late in the season, usually in the latter part of July or the first of August, while *T. inornata* appears early, that is from the latter part of April to the middle of May, and *T. vulgaris* issues from early May to July according to our records, which are meager for this species. Relatively speaking, *inornata* appears first, then *vulgaris,* and finally *transversa* and *punctata,* and since the wasps may live for a month or more, the species overlap considerably. The appearance of the different species at different seasons accounts for the supposition that Tiphia has several generations in a year; but our records show that under normal conditions there is only one annual brood in the latitude of Indiana.

Adult Tiphias are often found in June and later, on the flowers of such common roadside weeds as wild parsnip, aster, goldenrod, and milkweed, the males always predominating, but more often the female wasps are to be found in the fields, on the surface of the ground, or making short flights. The males are capable of making extended flights, but this the females are unable to do—except possibly for the first few days after emerging from the cocoons—owing to the larger size of the abdomen as compared with that of the wings. Usually the female wasps are found walking about over the surface of the ground in a quick, agitated manner, sometimes making short flights or jumps, with antennae continuously in motion, searching for evidences of their hosts. They make use of cracks, earthworm burrows, and possibly also of ant tunnels, in gaining an entrance into the soil, but not infrequently dig in directly, being admirably fitted to work their way through rather heavy soil with little apparent effort.

Outside of our cages, we have noticed copulation only in cultivated fields and along roadways, and always on the surface of the ground. Fertilization is not necessary to hatching, for we have often obtained fertile eggs from unfertilized females, but these eggs invariably yielded males. Phyllophaga grubs are the principal hosts of Tiphia, but we

have reared *T. punctata* from larvae attacking *Ligyrus gibbosus* and Anomala grubs, and have found Cyclocephala grubs bearing eggs of two species (probably *T. punctata* and *T. inornata*) in the field, these being however, exceptional cases. The female Tiphia stings if given opportunity, but the sting causes only a momentary itching, differing in this respect from that of the female Elis, which is sometimes quite painful.

The species of Tiphia under discussion look very much alike, and a brief general account of their appearance is sufficient here. Indeed the

FIG. 1. *Tiphia transversa* Say, female.

taxonomy of this group has never been satisfactorily worked out, which fact accounts for much of the confusion in literature. They are entirely shining black with grayish hairs on the head, thorax, abdomen, and legs; the abdomen is very noticeably constricted between the first and second segments (Fig. 1); and the wings vary from transparent to brown, more or less deeply tinged. The males average about one-half inch in length and are more slender than the females, which average about three-fourths

inch in length. The males are readily distinguished by the black, curved stylus or spine projecting upwards at the tip of the abdomen, sometimes, however, pressed to the body and more or less inconspicuous.

The egg, pure white when first laid, gradually becomes pale flesh-color and finally cream-color or pale brown. It is elliptical in form, averaging for the species under discussion 1.25 mm. in length and .5 mm. in thickness (Fig. 2).

Only the head of the larva protrudes when hatching begins (Fig. 3), but gradually the egg-shell splits longitudinally, exposing the body of the larva (Fig. 4). The body is pure glistening white and shows no characteristic markings, the segments being indistinct even in the mature larva (Fig. 5, and Pl. III, Fig. 1, 2).

The cocoon is oval, or egg-shaped, covered with soft, fluffy silk of a tan or golden brown color, and averages from 15 to 25 mm. in length (Pl. III, Fig. 4, and Pl. IV, Fig. 8, 9). Beneath the outer downy

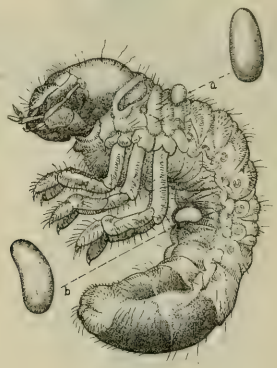

FIG. 2. White-grub showing position of Tiphia eggs; *a*, *Tiphia punctata* Rob., *b*, *T. transversa* Say, and eggs much enlarged.

covering are several more compact and firmer layers, capable of protecting against unfavorable soil conditions, such as excessive moisture.

The method used by the writer in studying the details of the life of Tiphia is very simple, and the cage was an ordinary three-ounce tin salve box. Two grubs, put in opposite sides of each box, were covered with soil, and properly watered. These preparations were made in advance of the introduction of the parasite to enable the grubs to make cells, which would give more normal conditions for the Tiphia. A female Tiphia was then introduced into the box and the grubs were examined for eggs every few hours if very exact records of oviposition

were desired. When a grub bearing an egg was found it was immediately transfered, with soil, to an ounce tin-box, which was then filled to the very top with soil so as to enable the grub to make a new cell. It was found that the egg was seldom displaced by this proceeding, whereas if the parasite was in the larval stage the grub would usually rub the larva off in forming a cell. Also for a grub bearing a Tiphia larva, obtained

FIG. 3. Tiphia larvae recently hatched and part of body still concealed by egg-shell.

FIG. 4. *Tiphia punctata* Rob., larva a few days old.

in the field or elsewhere, if was safer, after placing it in a similar box, to use, instead of soil, a packing of loose, partially rotted, damp sphagnum moss, or very loose muck soil. When the Tiphia cocoon had been completed it was transferred to a box containing an earthen cell. Each parasitized grub removed from the box containing the Tiphia adult was

FIG. 5. Mature Tiphia larva.

replaced by a healthy grub and the Tiphia was fed honey water about every other day.*

The life histories of the four common species studied at Lafayette are similar in many respects, and are as follows: The black digger-wasps *T. punctata* and *T. transversa*, and probably *T. vulgaris* also, issue from the cocoons during the summer, more often during June and July

* The writer takes this opportunity to acknowledge his indebtedness to Mr. D. G. Tower, who faithfully cared for the Tiphia experiments during the writer's absence August 15-30, 1915, and to Messrs. F. A. Fenton and S. L. Mason, who performed similar services in 1916.

(*T. inornata* earlier), feed on the flowers of such weeds as asters and parsnips or the honeydew of plant-lice (especially that of *Aphis maidis* Fitch), mate, and re-enter the ground to parasitize the common white-grub. The grub is first paralyzed, the wasp stinging it on the under side of the first or second thoracic segment, and an egg is then laid on the dorsum of the thorax, the under side of the abdomen, or elsewhere, according to the species of Tiphia. The egg is firmly attached to the body of the grub by a glutinous secretion which is at first colorless but later darkens to brown. In the process of oviposition the wasp, after paralyzing the grub, encircles the body so that the tip of its abdomen touches that point on the body of the host to which the egg is to be attached. The wasp then moves the tip of its abdomen back and forth in a fold or crevice of the skin for several minutes, all the while spreading the secretion which serves to attach the egg securely to the body of the grub. Under natural conditions the Tiphia attacks the grub in its earthen cell, but when a grub is exposed on the surface of the soil, the wasp stings it and then proceeds to undermine and gradually to bury

FIG. 6. Tiphia larva eating remains of grub after having killed it.

the grub before laying an egg on it. The egg having been laid the grub gradually returns to normal activity, the paralysis brought on by the sting of the wasp lasting only about an hour, or even less, and serving only to quiet the grub during the act of oviposition. Ordinarily but one egg is laid on a single grub, although in our cage experiments the wasp would in exceptional cases lay two or even three eggs on a single grub. That a second egg may be laid on a grub in the field if the first egg was dislodged is shown by the old egg-scars on grubs bearing an egg or larva, but we never have found a grub in the field which bore more than one egg or larva. Not infrequently the grub may molt soon after being parasitized, thus throwing off the egg or young larva, and once dislodged the parasite dies since it can not regain its position on the host. The egg hatches in four or five days, but in the beginning only the head protrudes. The larva immediately pierces the integument with its mandibles and begins to suck the body fluids, the grub apparently being unaware of its enemy. Within 5 or 6 hours the growth of the larva is sufficient to start an irregular longitudinal splitting of the egg-shell, and in 12 to

24 hours the shell is split its entire length and the body of the parasitic larva is exposed (Fig. 4). The larva remains affixed to the grub by the original egg-attachment (Pl. III, Fig. 5, 6), and the host is more or less active until a day or two before the larva matures, growth up to this point being quite slow. At this critical time the grub succumbs to the loss of its body fluids, the larva molts, and apparently having developed stronger mouth-parts proceeds to devour the entire grub, leaving only the chitinous head and portions of the shriveled hard skin (Fig. 6 and Pl. III, Fig. 1, 2). It was at first supposed that the Tiphia larva molted but once prior to spinning its cocoon and only a day or so before maturing, when it leaves the dorsal position on the host. However, an examination of the supposed skins arranged as leaflets beneath the larva and above the old egg-shell indicates that the larva molts five or six times before pupation. The length of the larval stage, that is the time until the cocoon is begun, averages about two weeks, being shortest in the warmer months and longest in the cooler ones. There is also an indication that the condition and activity of the grub has an influence on the growth of the larva.

After the larva has devoured its host it begins to spin the cocoon, first attaching loose threads of silk to all sides of the old grub-cell, fastening them more firmly at the small end of the cocoon with a "button" of silk (Pl. III, Fig. 3), and later spinning the inner layer, requiring from one to three days to complete the cocoon, judging from all external appearances. Unless the larva has a fairly uniform cell and one not too large it is unable to complete its cocoon, and will spin masses of silk at different places until it is exhausted and dies. Our observations indicate that most species remain in the cocoon over winter as larvae, although it is possible that other species, especially those issuing early in the spring, do pass the winter within cocoons as pupae or adults. The adults issue the following spring or summer, and in the latitude of Lafayette, Ind., all species of Tiphia have normally one annual generation. Several exceptions have been observed in the case of *T. punctata* and *T. transversa* in which the adults did not issue until the second season after spinning the cocoon.

Tiphia punctata Rob.

This is the commonest Tiphia observed by us, and according to the material contained in the National Museum and our own records, it occurs in Ontario, Canada, and in the states of New Hampshire, Massachusetts, Connecticut, Maryland, Virginia, Ohio, Indiana, Tennessee, Kentucky, Illinois, Wisconsin, South Dakota, Mississippi, Kansas, Texas, Louisiana, and New Mexico. Detailed studies of the habits and life history of this wasp were made at the Lafayette Laboratory in 1915, and the results are given herewith. Cocoons from which adults were obtained and used in these studies were collected in the following localities: Paxton, Ill., collected by G. N. Wolcott; Wellington, Kan., by E.

G. Kelly; Hagerstown, Wolfsville and Reids, Md., by J. A. Hyslop, H. L. Parker, and W. E. Pennington; Berwyn and College Park, Md., by R. J. Kewley; Hadley, Mass., and Greenwood, Miss., by H. E. Smith; Central City, Neb., by J. W. Vieregg; Pukwana, S. Dak., by C. N. Ainslie; Wakeman, O., by W. B. Hall; Buda, Tex., by W. E. Davis; Tappahannock, Va., by H. Fox; and Mt. Vernon, Oakwood, and Sheldon, Ill., Buck Creek, Frankfort, Huntingburg, Lafayette, Mt. Vernon, Switz City, and Washington, Ind., and Louisville, Ky., collected by members of the Lafayette Station staff.

The egg of *T. punctata* is invariably transversely placed on the dorsum of the thorax or first two abdominal segments (Fig. 2, *a*), most often on the third, or between the second and third, thoracic segments, usually just to one side of the median line in a fold of the skin, or, infrequently, on the median line. When laid to one side of the median line, the polar region, that is the anterior end of the egg, is invariably nearest the median line. The uniformity with which the female deposits its eggs is well illustrated by our experiments in 1915, in which eight wasps of this species laid a total of 205 eggs (Table I), and in 1916, in which seventeen wasps, caged with white-grubs simply to determine the position of the eggs, laid eggs on the dorsum of the thorax or first abdominal segments invariably, and these 25 females as well as all of the progeny in the above-mentioned 1915 experiments (a total of 52 males) were determined by Mr. A. B. Gahan as *T. punctata*. Of the 69 records kept of sex of adults issuing from cocoons collected in the field, 25 were males and 44 were females. In our cage experiments the largest number of eggs laid by a single female of this species was 42, with an average of 26 for the eight individuals observed, averaging a little more than one egg per day; but this is apparently below normal, and an examination of the ovary tubes of female wasps collected in the field indicates an egg capacity of 50 to 75. As will be noticed in Table I, the egg stage varies considerably in length, averaging about 127½ hours, or slightly more than five days. The methods used by the Tiphia in paralyzing the grub and subsequently ovipositing on it, as well as other details of the life history common to the other species here discussed, have been described in a preceding paragraph. The length of the larval stage, that is till a start is made on the cocoon, varies from 9 to 21 days and averages 14.4 days (Table I). This species almost invariably winters as a larva within the cocoon and has one annual generation. In our numerous experiments we have record of but one exception: an adult *Tiphia punctata* issuing July 17, 1916, from a cocoon collected at Tappahannock, Va., laid unfertilized eggs on grubs July 19–23, the larvae hatching, maturing, spinning cocoons, and issuing as adult male wasps by September 16 of the same year. In our experiments the adults issued from June 29 to September 6, most often during the latter part of July or first of August, and specimens were collected in the field as early as June 20 and as late as September 12. The adults live a maximum of 34 days in cages, and doubtless the normal life of the wasp

TABLE I. *Tiphia punctata*
Life-history Records obtained at Lafayette Laboratory, 1915-1916

Locality and date cocoons collected	Date adult issued	Length life as adult	No. eggs laid	Period of oviposition	Length of egg stage. Hours	Av. length egg stage. Hours	Length of active larval stage. Days	Av. length larval stage. Days	Dates adults issued
Huntingburg, Ind., April 19, 1915	*June 29, 1915	12 Days	9	2 Days	73—123	98	9.1—11.3	10.0	May 11 to July 26, 1916
Hagerstown, Md., April 2, 1915	July 23, 1915	25 Days	21	21 Days	74—216	137	11.5—21.3	15.0	July 28, 1916
Wolfsville, Md., December 1, 1914	July 20, 1915	27 Days	26	24 Days	80—217	150	14.5—20.3	15.5	July 28, 1916
Wolfsville, Md., December 1, 1914	July 23, 1915	9 Days	11	8 Days	71—132	108	13.1—17.6	16.0	July 28, 1916
Central City, Neb., April 30, 1915	July 25, 1915	34 Days	34	33 Days	80—205	140	14.5—16.2	15.3	Aug. 1, 1916
Hagerstown, Md., April 1, 1915	July 25, 1915	16 Days	23	15 Days	71—231	126	12.1—18.0	14.0	July 24, 1916
Hagerstown, Md., April 1, 1915	July 26, 1915	24 Days	42	23 Days	48—215	126	12.0—20.7	14.5	July 17-30 '16
Hagerstown, Md., April 1, 1915	July 27, 1915	28 Days	39	20 Days	70—193	136	12.1—21.3	15.0	July 17-28 '16

TABLE II. *Tiphia transversa*
Life-history Records obtained at Lafayette Laboratory, 1915-1916

Locality and date cocoons collected	Date adult issued	Length life as adult	No. eggs laid	Period of oviposition	Length of egg stage. Hours	Av. length egg stage. Hours	Length of active larval stage. Days	Av. length larval stage. Days	Date adult issued
N. Lima, O., Oct. 27, 1914	*July 3, 1915	9 Days†	8	3 Days	82—135	126	11.0—17.5	14	None issued
N. Lima, O., Oct. 27, 1914	July 3-7, 1915	16-20 Days	25	12 Days	73—149	122	10.5—14.7	13	None issued
Salem, O., Oct. 26, 1914	July 6, 1915	28 Days	35	26 Days	60—201	140	11.7—17.3	16	July 23, 1917‡

* Not placed with grubs till July 9.
† Accidentally killed.
‡ Only one adult issued, and that the second season after completing cocoon.

is a month or six weeks in the field. Table I gives the main points in the life history of eight individuals, but owing to the space it would require it seems impracticable to include the tables which we have drawn up showing all the details in the development of each individual larva.

Tiphia transversa Say

Although seemingly not so abundant as the species just discussed *T. transversa* (Fig. 1) seems to be fairly general in its distribution in the northern states and is usually to be found in the same surroundings as that species. According to specimens determined by Gahan in the National Museum and in our own collection, it occurs in the states of Vermont, New Hampshire, New York, Connecticut Pennsylvania, Maryland, Virginia, Ohio, Indiana, Wisconsin, and Arkansas.

The habits of oviposition agree with those already described except in the position of the egg on the grub. Of the 90 eggs laid by seven individuals all were placed transversely on the under side of the abdomen in a groove or fold of the skin (Fig. 2, *b*), usually just to one side of the median line and on segments 3, 4, 5, or 6, usually on 4 or 5. When laid to one side of the median line the polar region of the egg invariably is nearest the median ventral line. The largest number of eggs laid by a single female was 35, and as will be seen by the accompanying table (Table II) the date of emergence, length of egg stage, length of larval stage, etc., very closely approximate those of *T. punctata*. Dates of emergence in our breeding cages were from June 30 to August 21, and of those reared from cocoons collected in the field and recorded as to sex, three were males and eight females. Except for the position of the egg on the grub there is no noticeable or constant difference between the habits and life histories of the two species.

Tiphia inornata Say

This species, the largest of our Tiphias, is found, according to specimens in the National Museum and our own collection, in Canada, New Hampshire, Maryland, Ohio, Indiana, Illinois, and Wisconsin, and would therefore appear to be typically a northern species.

We have obtained eggs from only three individuals of *inornata*, but every one of the 22 eggs was laid on the under side of the thoracic or first abdominal segments, usually between the second and third thoracic segments and to one side of the median line, not infrequently relatively distant from the median line and between the legs. The egg period extended over a much longer time than for other species, that is, from 11 to 23 days, and this doubtless was due to the fact that the eggs were laid early in spring, when the temperatures were much lower. The adults of this species appear early in spring, as has already been stated, the dates of emergence ranging according to our records from April 8 to May 15, although we have found adults on wild parsnip flowers as

late as June 26. Aside from the facts that the species appears early in the season, that the eggs are laid on the under side of the thorax and require a longer period for development, and that the stage in which it hibernates is doubtful, the life history of the species agrees with that of *T. punctata.*

Tiphia vulgaris Rob.

This species is known to occur in the states of New Hampshire, Massachusetts, New York, Virginia, Maryland, Ohio, Indiana, Michigan, Illinois, Wisconsin, South Dakota, Kansas, Mississippi, Louisiana, and Alabama.

We have not yet obtained eggs from *vulgaris,* but from the fact that it is a common species in Illinois and that we have found grubs bearing eggs on the dorsum of the abdomen common in that state, together with the fact that this is the only species known to parasitize the white-grub whose egg-laying habits are unknown, and that, conversely, the species laying eggs on the dorsum of the abdomen is the only one unknown, it is reasonable to believe that this species does lay its eggs on the dorsum of the abdomen near the anal end.

According to our meager records this species issues from May 8 to June 23 in the latitude of Indiana, but further data will probably show it to agree more nearly with *punctata* in the time of its appearance.

Four other species of Tiphia have been reared at the Lafayette Laboratory but we have no positive evidence of their host relations.

T. robertsoni Mall. was reared from cocoons collected at Wakeman, O., and Bells Valley, Va., and in the field where the former collections were made white-grubs were very abundant. Our dates of emergence are July 30 and 31.

T. clypeata Rob. has been obtained by us from Lafayette (Ind.) only, and the dates of collection were widely separated, some in May and others in October.

T. reticulata Mall. was reared by us but once, and the adult issued July 3—from a cocoon collected by Mr. H. E. Smith at Agawam, Mass.

T. conformis Mall. was obtained from cocoons collected at Sheldon Ill., Frankfort, Ind., and Richland, Mich., and the adults issued from July 24 to August 4. The fields at Frankfort were well infested with Anomala grubs, while the fields at Sheldon and Richland contained a good infestation of Phyllophaga grubs, but positive evidence of their host relations was not secured.

Enemies of Tiphia

Three species of bombyliid flies representing two genera (Exoprosopa and Anthrax) have been reared from Tiphia cocoons. Of these, *E. fascipennis* Say, which was first recorded as a Tiphia parasite by Dr. S. A. Forbes (26), is the most common in our rearings, although it would appear that none of the species are sufficiently abundant to lessen noticeably the value of Tiphia as a white-grub parasite. This

FIG. 7. A hyperparasite (*Exoprosopa pueblensis* Jaenn.)—a parasite of Tiphia.

species has been reared at the Lafayette Laboratory from Tiphia cocoons collected in various parts of Illinois and Indiana, the adults issuing during the month of July. Mr. H. E. Smith obtained an adult July 7, 1913, from Tiphia cocoons collected at Wellington, Kansas, and E. G. Kelly informs me that he has also reared it from the same locality and

FIG. 8. *Exoprosopa pueblensis* Jaenn., pupa.

host. From the fact that Tiphia cocoons collected in the fall were infested with these flies (*Exoprosopa fascipennis*), it is certain that infestation originates in the summer or fall previous to emergence, and since they are incapable of entering the soil, and in view of the further

FIG. 9. Tiphia cocoon from which the hyperparasite (Exoprosopa) has issued.

FIG. 10. Tiphia cocoon showing emergence hole made by the adult.

fact that they frequent flowers and feed on honeydew produced by aphids at the same time that the Tiphias are active, it is conceivable that the flies oviposit on the flowers or possibly directly on the Tiphias and that their eggs are carried away by the wasp and deposited with its own egg on the Phyllophaga grub.

Exoprosopa pueblensis Jaenn. (Walton and Cole det.), a species remarkably similar to *fascipennis,* was reared by E. G. Kelly from a Tiphia cocoon obtained at Wellington, Kansas (Fig. 7, 8).

Anthrax parvicornis Coq. was obtained by the writer in 1913 from Tiphia cocoons collected either at Rockford, Ill., or Lafayette, Ind., the adult issuing previous to June 30. The exit hole of this species, as well as that of the two species mentioned above, is made in the Tiphia cocoon

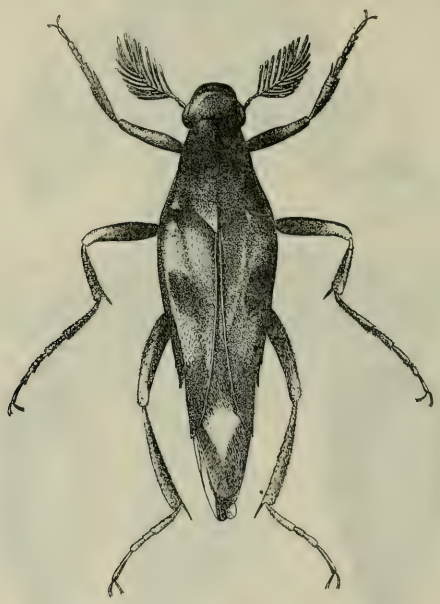

FIG. 11. A hyperparasite (*Macrosiagon pectinatus* Fabr.)—a parasite of Tiphia.

by cutting out a circular cap at the larger end of the cocoon, the cut being as clean as though made with a sharp knife (Fig. 9, and Pl. III, Fig. 7). It differs in this respect from the emergence hole made by the Tiphia adult, which is ragged, and although always made at the large end, is at one side of the tip (Fig. 10).

The interesting rhipiphorid beetle *Macrosiagon pectinatus* Fabr. (Fig. 11) was first recorded as having been reared from Tiphia cocoons

by Dr. C. V. Riley in 1874 (59), and its parasitic habits have since been occasionally referred to in literature. We have reared it from Tiphia cocoons collected in Illinois and Indiana, once from a cocoon collected by H. E. Smith at Hadley, Mass., and again from cocoons collected by J. A. Hyslop at Hagerstown, Md., and in all cases the beetles issued in July excepting the last collection—which issued May 15—and one from Mt. Vernon, Ill., which issued August 29. We have also reared a species determined by Mr. E. A. Schwarz as *Macrosiagon 8-maculatus* Gerst. from a mixed lot of Tiphia cocoons collected at Lafayette, Ind., and Rockford, Ill., the adult in this case issuing July 1; and the same species was reared from the cocoons of a Ligyrus parasite, *Campsomeris dorsata* Fabr., by W. Nowell (53) in Barbados. Whether or not *pectinatus* and *8-maculatus* are distinct species is not agreed upon by systematists, the species being distinguished only by the elytral markings.

It is supposed that these rhipiphorid beetles are primary parasites of Tiphia, and it is probable that the egg is laid on or near flowers frequented by Tiphia adults, or possibly on the Tiphia itself, and that the egg or the recently hatched rhipiphorid larva becomes attached to the wasp and is in due course deposited on the Phyllophaga grub at the same time that the Tiphia deposits her own egg.

Lugger (46) speaks of a hymenopteron which is parasitic on Rhipiphorus, and we have occasionally collected cocoons behind the plow which were pierced with small holes resembling emergence holes of a small parasite.

It is interesting to note that the common English sparrow seems fond of Tiphia—at least in the 92 stomachs of this bird examined by Dr. Riley (61), 10 contained the remains of Tiphia adults.

The Banded Digger-wasps (Elis spp.)

Five species belonging to the genus Elis have been reared from cocoons collected in fields infested by white-grubs. Two of these, however, are doubtfully mentioned as parasites, no proof of their habits other than circumstantial evidence having been obtained. The cocoons are to be found more or less common behind the plow, especially in fields where white-grubs occur in abundance. The life history of only one species (*E. 5-cincta*) has been studied, but it seems likely that other species of Elis will agree with it in all essential details.

Elis 5-cincta Fabr.

This scoliid wasp was first reported as a white-grub parasite in 1912, under the name *Myzine sexcincta* Fabr., by Flint and Sanders (22), and according to their observations it was found as abundant as Tiphia in certain parts of Illinois. Although the present writer has never found it so abundant it is common in some localities and no doubt is a very important aid in the natural control of white-grubs. Several species of Elis are supposed to be parasitic on Phyllophaga grubs, but *5-cincta* is undoubtedly the most common where we have studied it, and

has been collected by us in Wisconsin, Iowa, Illinois, Michigan, and Indiana. It has been reared by E. G. Kelly and H. E. Smith from cocoons collected at Wellington, Kansas; by W. R. McConnell and H. E. Smith from cocoons collected at Greenwood, Miss., by C. N. Ainslie from cocoons collected at Elk Point, S. Dak.; and by J. A. Hyslop from cocoons collected at Hagerstown, Md.

The habits of Elis differ noticeably from those of Tiphia, primarily in the fact that it permanently paralyzes the grub before laying an egg. Briefly, the life history and habits are as follows: The adults issue in July and feed on the nectar of flowers, more especially sweet clover. At night the males rest on weeds and similar vegetation, the females entering the soil for oviposition. The method used by the wasp in attacking the grub is similar to that of Tiphia, but its sting causes permanent paralysis. After the grub is paralyzed, an egg, which hatches in about two days, is laid loosely on the under side of the abdomen of the grub. At first the larva consumes only the body fluid, as does Tiphia, but when nearly full-grown it eats the grub, leaving only the chitinized parts such as the head; it is therefore an ectoparasite throughout its life. Feeding rapidly, the larva consumes the grub and completes its growth in about 5 days, and requires from 1 to 2 days for the making of its cocoon—a total of only 8 or 9 days from the time the egg is laid until the cocoon is completed. Within the cocoon (Pl. IV, Fig. 10, 11) it remains as a larva over winter, pupating in spring, and issuing as an adult wasp in July.

In 1914 notes on the life history of *E. 5-cincta* were obtained by confining numbers of Elis collected on sweet clover (*Melilotus alba*) in a 12-inch flower-pot cage containing white-grubs. The wasps were given honey water as well as sweet clover blossoms, and the grubs were examined every few days for eggs. Elis adults were first placed in this cage July 7, 1914, but eggs were not found until July 23. According to our observations this species is not parthenogenetic, but in confinement unfertilized females do frequently sting and paralyze grubs. In this process the wasp wraps its abdomen about the first or second thoracic segment of the grub much as does Tiphia and stings the host on the ventrum of the thorax near the head. After a short struggle the grub becomes motionless and limp, in which condition it remains until devoured by the Elis larva or until it dies. We have kept grubs which have been "stung", but upon which the wasp failed to lay an egg, for over a month in an undecayed condition although to all appearances dead. The egg is white with a faint cream-tint, elliptical and slightly curved, 3 mm. in length by .8 mm. in width. It is laid medially on the under side of the body (Fig. 12, and Pl. V, Fig. 13), usually on the sixth or seventh abdominal segment, and not glued tightly to the body as is the Tiphia egg. Only one egg is laid on a single grub. Upon hatching, the larva immediately begins to feed on the body juices, the grub gradually shriveling from the loss. When almost grown, the parasite devours the grub, leaving only the chitinized parts, such as the head.

The Elis larva is entirely white, including the head, the body shining and semitransparent. After completing its growth it commences at once to spin its cocoon, within which it remains over winter as such, pupating the following spring. The first egg observed was laid between 2:00 p. m., July 23, and 10:45 a. m., July 25, the date of oviposition probably being July 24. The grub bearing this egg was placed in a one-ounce tin box, and the egg hatched previous to 3:00 p. m. July 27, by which time the Elis larva was 6.7 mm. in length and 2.5 mm. in width (Pl. V, Fig. 14); at 10:00 a. m. July 28 it was 13.1 mm. long and 5.2 mm. wide (Pl. V, Fig. 15); at 6:00 p. m. July 30, 19 mm. long, and at 10:00 a. m. July 31, 21 mm. long (Pl. V, Fig. 16, 17). By this time the larva had nearly consumed the grub, finishing it by 5:30 p. m. July 31, when it measured 24 mm. in length. At 6:00 p. m. July 31, it had commenced to spin its cocoon, which it completed by 10:00 a. m. August 2. The larva died within the cocoon. In another case two paralyzed grubs were found in the cage at 2:30 p. m. July 23, each bearing an Elis larva on the under side of the body, one of which measured 7.6 mm. in length and the other 10.5 mm. The dates of egg-laying and hatching were not obtained. The larger one finished feeding and started its

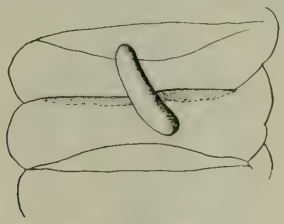

FIG. 12. *Elis 5-cincta* Fabr., egg on under side of 6th and 7th abdominal segments of white-grub.

cocoon by noon July 26, and completed the cocoon previous to 5:00 p. m. July 28. From this an adult male *Elis 5-cincta* issued July 17, 1915, almost a year after the egg was laid. The smaller larva had nearly devoured the grub at noon of July 26, and by 10:00 a. m. July 27 it had begun the framework of its cocoon, which it completed by 5:00 p. m. July 28. An adult male *Elis 5-cincta* issued from this cocoon a year later, July 8, 1915.

Our field observations corroborate the results obtained in cages, and they further indicate the months of July and August as the ones during which the adults are actively ovipositing. At Mt. Vernon, Ind., on August 28, 1916, recently made cocoons, larvae in act of spinning cocoons, and recently hatched larvae were obtained in one field. From cocoons collected by R. J. Kewley, D. G. Tower, and the writer, at

Inglefield, Lafayette, Lewis, and Washington, Ind., and at Battle Creek, Mich., adults issued between June 28 and July 11; from cocoons collected by J. A. Hyslop and H. L. Parker at Hagerstown, Md., adults issued June 26 to June 29; and Mr. H. E. Smith obtained an adult as early as June 18 from a cocoon collected at Wellington, Kan.

In addition to the localities already given, *E. 5-cincta* has been collected by Mr. Ed. Foster at Abita Springs, La., during July and August according to Mr. G. N. Wolcott, and listed from Missouri by Phil. Rau, who observed the "sleeping" habits of the males (58), and from New Jersey.

The adults feed during the day on the nectar of sweet clover flowers almost exclusively. In one exceptional case R. J. Kewley and F. A. Fenton, of the Bureau of Entomology, found several individuals feeding on wild aster flowers. Collections were made on sweet clover flowers during the season of 1914 at Lafayette, Ind., by R. J. Kewley, A. F. Satterthwait, and the writer, and during 1915 by Kewley. The first collections were made July 9 and the last August 31, except in 1915, when one isolated collection was made as late as September 28. It is evident from these recorded observations, made at all hours of the day, that a majority of the females frequent flowers during the morning hours. Ordinarily the female wasps begin to appear about 8:00 a. m., or a little earlier, and until 10:00 a. m. scarcely a male can be found flying. After 10:00 a. m. the males are found in increasing numbers, and the females in decreasing numbers, very few of the latter being found during the afternoon. Ninety-five per cent. were of one species, *Elis 5-cincta,* but occasionally specimens of *E. atriventris* and *E. interrupta* were taken. At night the males have the habit of resting in "colonies" on the tops of weeds and other vegetation.

All of the species of Elis here considered are similar in general appearance and are well illustrated in Figure 13. The black thorax is more or less distinctly marked with yellow, the abdomen black and conspicuously marked with transverse yellow bands, and the wings are transparent and more or less shaded with brown. The sexes are readily distinguished, the male wasps having a more slender body and a prominent curved, hook-like stylus (Fig. 13, *a*) at the apex of the abdomen, which is absent in the female. The cocoon (Pl. IV, Fig. 10, 11) is similar for all species, differing only in size. It is uniformly elongate-elliptical, chocolate-brown, rather smooth, the inner lining thin and parchment-like, and these characters readily distinguish it from the ovate, woolly, paler brown Tiphia cocoons. The adult wasp issues by cutting a hole in one side near one end of the cocoon.

We have never reared parasites from Elis, but Mr. Otto Swezey (72) reared a bombyliid (*Chrysanthrax fulvohirta* Wied.; Pl. IV, Fig. 12) and two mutillids (a male *Mutilla castor* Blake and a female *M. ferrugata* Fabr.) from cocoons of *E. sexcincta* (=*E. 5-cincta*) collected at Urbana, Ill.

Elis atriventris Gahan

This species (Fig. 13) was described and referred to as a parasite of Phyllophaga by Mr. A. B. Gahan (29), the specimen having been reared by Mr. C. N. Ainslie from cocoons collected at Elk Point, S. Dak., April 19. According to the original notes some of these cocoons bore Phyllophaga remains; but since several species (*E. atriventris*, *E. 5-cincta*, and *E. illinoisensis*) were reared from the lot it was not definitely shown that this species was parasitic. However, the writer has since reared *E. atriventris* from cocoons collected at Lafayette, Ind., which bore unmistakable remains of Phyllophaga grubs, and from

Fig. 13. *Elis atriventris* Gahan, female: *a*, lateral view of tip of abdomen of male, showing stylus.

cocoons, bearing like evidence, collected at Ashboro, Ind., which facts give us reasonable assurance of the truly parasitic habits of this species. The adults issue during July and are to be found in company with *5-cincta* feeding on such flowers as white sweet clover.

Elis interrupta Say

We have reared *E. interrupta* from cocoons collected at Hoopeston, Ill., and Lafayette, Ind., the adults issuing July 30 and September 6,

respectively. Inference of their parasitic habits is based on the remains of Phyllophaga grubs found attached to the above-mentioned cocoons collected at Lafayette. This species was also reared from cocoons collected behind the plow at Wellington, Kan., by Mr. H. E. Smith, the adult issuing July 5, 1913. The adults are to be found feeding on flowers of such roadside plants as the white sweet clover.

Elis obscura Fabr.

Although there is no direct evidence of the parasitic activities of this or the following species of Elis the fact that their cocoons are to be found in fields infested with white-grubs makes it quite likely that they will prove to have parasitic habits similar to those of the species already discussed. We have reared *E. obscura* from a cocoon collected by Mr. J. A. Hyslop at Hagerstown, Md., the adult issuing June 29, 1915; Mr. W. R. McConnell reared it from cocoons collected at Greenwood, Miss., the adults issuing May 30–31, 1913; and Mr. Harrison E. Smith obtained several adults between June 3 and 17 from cocoons collected in plow furrows at the same place.

Elis illinoisensis Dalla Torre

Our records show this species to have been reared from cocoons collected behind the plow by Mr. C. N. Ainslie at Elk Point, S. Dak., and by Mr. H. E. Smith at Greenwood, Miss., the adults in the latter case issuing June 3–17, 1914. The status of this species in relation to white-grubs is the same as that of *E. obscura.*

Tachinid and Dexiid Parasites

Five species, two tachinids and three dexiids, have been reared from white-grubs of the genus Phyllophaga. Two of these species (*Microphthalma disjuncta* and *Ptilodexia harpasa*) are of considerable value in certain areas, and it appears that their occurrence in beneficial numbers depends largely on soil conditions which will enable the young larvae to easily penetrate the soil and so come in contact with their hosts. Two others of the five species, *Microphthalma pruinosa* and *Ptilodexia abdominalis,* can not be regarded as important enemies because of their rarity; and the remaining species (*Myocera cremides?*) is more often a parasite of *Serica* and grubs of similar habitat, than of Phyllophaga. Another dexiid (*Prosena lacertosa* v.d.W.), briefly treated in a subsequent paragraph, has been reported as a parasite of white-grubs in Mexico.

Microphthalma disjuncta Wied.

This species, under the name *M. nigra,* was first recorded as a parasite of white-grubs by Dr. S. A. Forbes (24) in 1891, who subsequently reared it from white-grubs (25 and 26), as has also the writer (16). Mr. D. W. Coquillett (13) reports it as reared by the late Theo. Pergande from a puparium found in the skin of a grub August 12, 1891, at Washington, D. C., the adult issuing October 15.

The species has a wide distribution as shown by its reported occurrence in New Hampshire, Massachusetts, District of Columbia, New Jersey, Pennsylvania, Michigan, Indiana, Illinois, South Dakota, Kansas, California, Texas, Mississippi, and Georgia. We have reared it from grubs collected at Hagerstown, Md., by H. L. Parker; from Hadley, Mass., and Chelsea, Vt., collected by H. E. Smith; from Ercildoun,

FIG. 14. *Microphthalma disjuncta* Wied., male.

Pa., by J. C. Hamilton; from Crooks, S. Dak., by C. N. Ainslie; and from Lafayette and Lewis, Ind., Deford, Farmington, and Holly, Mich., and Swanton, O., by A. F. Satterthwait, D. G. Tower, R. J. Kewley, and the writer. Mr. H. E. Smith reared it from grubs collected at Broad Brook, Conn., in 1915, and from Greenwood, Miss., in 1914. Mr. Norman Criddle writes January 10, 1918, that he has reared *M. disjuncta* from white-grubs collected in Manitoba.

The adult is a rather large fly (Fig. 14, and Pl. VI, Fig. 22, 23), varying in length from 9 to 14 mm. The thorax is grayish above with

more or less indistinct longitudinal black streaks; the abdomen, black with the anterior margin of each segment banded with grayish bloom, giving the appearance of alternate bands of gray and white; the entire body, including the head, set with conspicuous long hairs or bristles; and the transparent wings tinged with brown at the base and the wing veins faintly margined with brown. The flies are to be found from May till September, most often in June or July, occasionally at lights, and frequently on the ground in fields, especially corn fields. They are exceedingly alert and difficult to capture, although they will remain quiet and apparently unsuspecting until one approaches quite near, and when disturbed they usually light only a few feet ahead. Pairs have been observed in copula on the ground in corn fields in June and July. The female oviposits in the ground, probably in cracks, and the larva enters the grub, but just how this is effected has not been determined. Our observations show that oviposition occurs in fields either cultivated or in grass, probably more frequently in the former although our records are conflicting on this point. The small maggots remain within the grub until mature, passing the winter therein and completing their

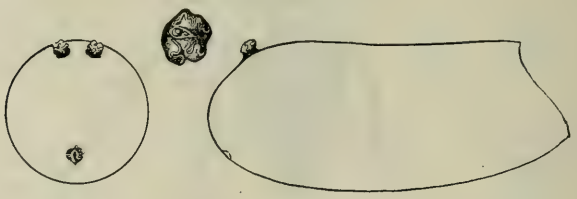

FIG. 15. *Microphthalma disjuncta* Wied., puparium: anal end, and one posterior spiracle.

growth the following spring. The infested grub feeds and acts normally until within a day or two of its death, which would indicate that the maggots feed entirely on the fatty tissues at first, not attacking the vital organs until nearly full-grown. The first indication of the presence of these parasites is the death of the grub and the coincident appearance of the anal end of the maggot through the skin of the grub, the conspicuous posterior spiracles showing prominently (Pl. VI, Fig. 18). About the same time the grub begins to liquefy (Pl. VI, Fig. 20), apparently melting away, and frequently the parasitic larva pupates within 24 hours from the time it is first noticed (Pl. VI, Fig. 19, 24).

Maggots were observed, in grubs collected in the field, as early as April 26 and until August 17, and the earliest and latest dates of pupation observed were on the same dates. Flies from caged material issued from May 24 to September 4, the length of the puparium period ranging

from 15 to 43 days, apparently depending largely on temperature and quite likely also on moisture conditions. Although Phyllophaga grubs are more often attacked than others, we have reared this parasite also from grubs of *Cotalpa lanigera,* and it seems not unlikely that it may infest other large scarabaeid grubs that occur in cultivated fields. The maggot and puparium are distinguished from the related dexiids by the posterior spiracles, shown in Figure 15. In no case have we found more than two larvae infesting a single grub, the number usually being one to a grub.

As has been shown, *M. disjuncta* has a wide range of distribution and in certain areas it undoubtedly has a marked influence on the abundance of grubs. In a collection of grubs taken at Farmington, Mich., June 12, 1916, over 25 per cent. showed *disjuncta* parasitism. We have found it especially abundant in the eastern part of Michigan near Lake Huron, which would indicate a preference for, and an ability to live and seek its host advantageously in, sandy or sandy loam soils, as might be expected from our knowledge of its mode of life.

Microphthalma pruinosa Coq.

Eight Phyllophaga grubs were received at the Lafayette Station June 14, 1915, from Framingham, Mass., where they were reported to be injuring pine and spruce seedlings. They were placed in individual one-ounce tin boxes, and on July 16 one was dead, and in the semi-liquid remains the anal ends of two dipterous maggots protruded through the body-wall, exactly as had already been observed for the parasite *Microphthalma disjuncta.* By ten o'clock the following morning (July 17) one of the maggots had formed a puparium, which, however, was still uncolored. By 2:30 p. m. the puparium had taken on its natural reddish brown color, and between 2:30 and 5:30 p. m. the second maggot pupated. One adult, determined by W. R. Walton as *M. pruinosa,* issued August 27, but the record for the second adult which issued was lost. From the 7 remaining grubs 4 adults were obtained, all being *Phyllophaga anxia* (=*dubia,* form *insperata*), and as the grubs had been carefully examined on receipt and no specific difference found, it is very probable that the species destroyed by this parasite was *P. anxia.* This seems to have been the first recorded observation (16) concerning the host relations of this tachinid. We have since reared a single specimen of this species from a grub collected at Chelsea, Vt., May 31, 1916, by Mr. H. E. Smith. In this case the grub died July 7, which was coincident with the first appearance of the parasitic maggot, the adult fly issuing September 1 of the same year.

M. pruinosa seems to be widely, though sparsely, distributed, for it was described from specimens collected in New Mexico and Mexico, and Dr. Aldrich has a specimen which he collected at Brookings, S. Dak., in 1891 or 1892. Apparently the species is of little economic importance in controlling white-grubs, owing to its scarcity.

PTILODEXIA HARPASA Walk. (=TIBIALIS Desv. of Coquillett and authors)*

This fly, first recorded as a white-grub parasite by the writer under the name *tibialis* (16), has a wide distribution, occurring, according to published records, in Nova Scotia and Ontario, Can.; and in New Hamp-

FIG. 16. *Ptilodexia harpasa* Walk., male.

shire, New Jersey, Minnesota, Texas, and New Mexico. We have reared it from Phyllophaga grubs collected by H. E. Smith at Chelsea, Vt., and by the writer at Austin, Tex. Smith writes that he has reared

*Concerning the status of this species I quote the following note furnished by Dr. J. M. Aldrich:

"This species has been frequently referred to as *Ptilodexia tibialis* Desvoidy, which is evidently different as its describer placed it in a genus characterized by a petiolate apical cell. Austen, in Annals and Magazine of Natural History, Vol. XIX, p. 344, reports from an examination of the type of *harpasa* that it is the same as *tibialis*. Since he evidently used the latter in the accepted but erroneous sense, his statement seems to justify the use of *harpasa* for the present species."

it from grubs collected at Broad Brook and Orange, Conn., and at Hadley, Mass., and Mr. N. Criddle writes of it January 10, 1918, as a white-grub parasite in Manitoba, Can. In addition we have reared it from grubs of *Aphonus pyriformis* collected by D. J. Caffrey at Las Vegas, New Mex., and by Caffrey and G. W. Barber at Maxwell, New Mex. It was also reared by W. E. Pennington from unknown scarabaeid larvae collected February 17, 1916, in a decayed stump at Gainesville, Fla., and one adult was reared, which issued March 27, 1916.

As with *Microphthalma disjuncta,* the grub is not seen to be parasitized until the parasitic larvae are practically full-grown. The habits of the larvae and their effect on the grub are like those of *disjuncta* except that there is not the conspicuous liquefying effect on the grub (Pl. VI, Fig. 21), previously mentioned for that species. Apparently

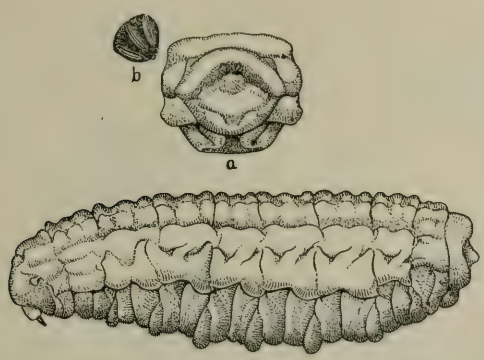

FIG. 17. *Ptilodexia harpasa* Walk., larva, lateral view; *a*, view of posterior end, showing spiracles; *b*, a spiracle much enlarged.

the eggs are laid in early fall and the small maggots enter the grub the same season, remaining within it over winter and completing their life cycle the following spring. From grubs collected at Chelsea, Vermont, May 8, maggots were observed from May 16 to 20, forming the puparia usually a few days thereafter. From grubs collected at Austin, Texas, April 29, Ptilodexia larvae were first observed from May 18 to June 18. In these cases adult flies issued between June 11 and July 10, the puparium stage varying from 20 to 32 days. Grubs collected in New Mexico May 10 and 24 showed parasitism from May 20 to July 7, while larvae from the same locality collected September 7 and confined in indoor cages showed parasitic larvae from October 7 to February 23. The number of larvae infesting a single grub varies from 1 to 7 and the average from our 50 examples is 2.3+.

In all cases known to us where this species has attacked grubs the percentage of infestation has been marked. For instance, in one lot of grubs collected by Mr. Smith at Chelsea, Vt., over 35 per cent. were infested by it, while more than 10 per cent. of our Austin, Tex., collection showed Ptilodexia parasitism, and over 45 per cent. of the Aphonus grubs collected by Caffrey and Barber at Maxwell, N. Mex., September 7, 1916, were parasitized by this species. These few examples indicate the importance of this parasite in some sections.

The fly, which has rather remarkably long legs, is well shown in Figure 16, and Plate VII, Figure 25, and the larva and puparium, as well as the characteristic posterior spiracles, are shown in Figures 17 and 18.

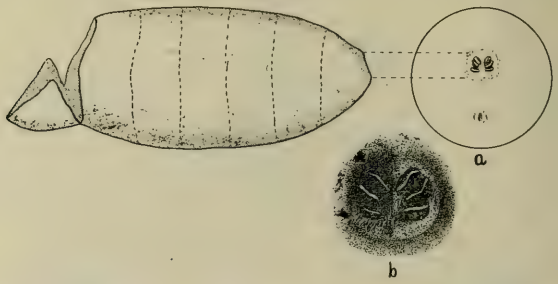

FIG 18. *Ptilodexia harpasa* Walk., puparium; *a*, posterior end, showing position of posterior spiracles; *b*, the spiracles, much enlarged.

PTILODEXIA ABDOMINALIS Desv.

This species and the following one are here recorded as parasites of Phyllophaga on the authority of Mr. Norman Criddle, whose notes are here given through the courtesy of Dr. C. Gordon Hewitt : *P. abdominalis** was reared from larvae of *Phyllophaga rugosa* collected in Manitoba. The larvae entered the earth to pupate after killing the grubs as does *P. harpasa,* and the two examples reared, issued August 31 and September 1, 1915, respectively.

This dexiid has heretofore been recorded in literature only from Nova Scotia.†

MYOCERA CREMIDES Walk.? (of authors).‡

Mr. Criddle reared a number of individuals of this species, six or more issuing July 7 from a grub of *Phyllophaga anxia* or *P. nitida,*

* Determined by J. D. Tothill.
† This species is listed in Aldrich's Catalogue (1) as *Dexia abdominalis.*
‡ Determined by C. W. Johnson. J. M. Aldrich informs us that this wide-spread species is known in collections under the name *cremides,* but that it does not agree with Walker's description of that species and is probably undescribed.

others issuing July 15 and August 4 from grubs of Serica sp., and one August 9, from a grub of *P. drakii.* He writes me January 21, 1918, that "*Myocera cremides?* appears to prefer *Serica* larvae and is evidently an inhabitant of semi-wooded areas."

The species is wide-spread, occurring according to published records and specimens in Aldrich's collection, from New Jersey to Oregon, the states and provinces represented including New Jersey (under the name *simplex* in "New Jersey Insects"), Indiana, Iowa, Minnesota, Manitoba, S. Dakota, Idaho, and Oregon.

Prosena (Mochlosoma) lacertosa v. d. Wulp

This dexiid fly was found by Mr. C. H. T. Townsend during August 1909, abundant in pastures near Colonia Garcia, Mexico, principally on flowers of Rudbeckia. The flies, according to Mr. Townsend, were at the time of his visit issuing in great numbers from puparia in the soil, and the pastures in the vicinity were heavily infested with white-grubs, from which it was concluded that *P. lacertosa* is parasitic upon white-grubs (77). This inference is probably correct, and this species is apparently of considerable importance in Mexico as a white-grub enemy.

Hymenopterous Enemies Recorded

Ophion bifoveolatum Brullé

This large, slender-bodied, reddish brown ichneumon-fly (Pl. VII, Fig. 30), which is distributed throughout the United States, has not been reared by us from larvae actually found attacking grubs. The first reference to this insect as an enemy of white-grubs seems to have been made by Dr. C. V. Riley (63), who based his record on observations made by Prof. F. M. Webster at Lafayette, Ind. Professor Webster obtained a number of specimens of this species from a cage containing white-grubs, and this appears to be the only reason for the conclusions published by Riley. Dr. S. A. Forbes (26) records it as a parasite of grubs, basing his conclusions on his office notes—which he kindly permits the writer to publish here. The first note is as follows: "Leroy, Ill., Sept. 1, 1906. E. O. G. Kelly. *Ophion* cocoon found in a sod field with part of the skin and head of *Lachnosterna* grub enwrapped with cocoon. To rear adult. April 27, 1907. *Ophion* adult [later determined as *O. bifoveolatum*] has emerged, pinned it with cocoon as accessions No. 37368. Davis." Another note furnished by Dr. Forbes reads—"*Ophion* sp., Kelly. Mackinaw, Ill., 10/06. Sending to insectary."

The adults issue for the most part during April, and the larva is probably ectoparasitic, as is Tiphia. The larva becomes full-grown and spins its cocoon previous to August, passing the winter within the cocoon, which is dull brownish, frequently darker at the extremities, smooth and uniform in thickness at the ends as is the cocoon of Elis, but much shorter, measuring about half an inch in length and a quarter of an inch in thickness.

Our official records contain the following note which probably refers to this species: Mr. A. F. Satterthwait collected a Lachnosterna bearing a Tiphia-like larva, in a field at Nortonville, Ky., August 6, 1915, and when received at Lafayette the following day the grub was dead and the larva spinning its cocoon. The cocoon proved to be that of an ichneumonid, but was accidentally lost before the adult issued. It is not unlikely that it was an Ophion cocoon.

If this species is a parasite of Phyllophaga only, one would expect to find it common in infested fields, since the adults are said to be common and wide-spread. The above questionable record is the only available Bureau record bearing on this point, notwithstanding the fact that we have collected and reared thousands of grubs from all parts of the United States.

Pelecinus polyturator Dru.

Only one record of this species as a white-grub parasite has been published, and this by Dr. S. A. Forbes (25), who in 1892 reared it from a Phyllophaga grub obtained at Champaign, Ill., May 9, the adult issuing August 26 of the same year. There seems to be no question as to the authenticity of the record notwithstanding the fact that this still stands as the only observation on the larval history of Pelecinus.

The female of this parasite is quite remarkable. The entire body is jet-black, and the abdomen an inch and a half long (Pl. VII, Fig. 29), differing markedly from the male, which lacks the long, slender-jointed abdomen.

In 1914 and 1915 female specimens of *P. polyturator* were found rather common by R. J. Kewley in an isolated area four miles north of Lafayette, Ind., although not a single male was observed. July 31, 1914, he collected nine females; August 3, eight; August 8, fifteen; August 27, three; September 5, one; and September 6, eleven. The following year (1915) he collected two on August 26; three August 31; and ten September 8, none being found after this date although weekly searches were made, nor were we able to find the species in any other area. The locality in question is a wooded glen along the Wabash River and mostly shady and cool. The bottom is rather swampy from the overflow of a small stream of spring water, and is matted with grass, water plants, and other vegetation. The specimens mentioned above were collected in flight or resting on foliage. The females are slow fliers and travel close to the ground, seeming to prefer sunny spots near stagnant water, and never resting long in one spot.

The females collected were placed in cages covering pots containing white-grubs. On two occasions a Pelecinus was seen with the abdomen inserted to the thorax in a crack in the ground. In one case the insect withdrew the abdomen half a minute after being observed, and then spent several minutes in cleaning the body with the feet. In the other case the abdomen was thrust into the soil several times within two or three minutes. Probably the females oviposited in the soil, which was not examined at the time, but no Pelecinus was reared, nor could we

find traces of Pelecinus parasitism when the contents of the cage were examined the following spring.

The Tawny Bee-fly (Sparnopolius fulvus Wied.)

The larva of this bee-fly was first reported as an enemy of white-grubs in 1907 by Dr. Forbes (26), his assistant, Mr. E. P. Taylor, having found it attached to the back of a Phyllophaga grub at Elliott, Ill., August 25, 1904. Whether it is ectoparasitic as are the Tiphias or predaceous as are the Asilidae seems not to have been positively determined. Probably it is in a sense parasitic for, owing to its small size, it can and probably does obtain all the necessary food from a single grub; but since the fly can not enter the soil to lay its eggs directly on the grub,

Fig. 19. *Sparnopolius fulvus* Wied., female.

and probably, therefore, oviposits in a crack of the ground, the larva upon hatching from the egg must search through the earth for its host, the grub, and is to this extent predaceous.

This species has been reported from such widely separated localities as New Jersey, New Mexico, and Illinois, and although a common insect it is probably not of prime importance as an enemy of the white-grubs.

The adult is to be found on vegetation and on flowers in August and September. It is nearly as large as the common house-fly, but unlike the latter it is covered with erect, yellow, fur-like hair which gives it a look more like that of a bee than of a fly, and hence it has received the common name of bee-fly (Fig. 19). The pupa, which has been described in detail by J. R. Malloch (47), is fully exposed and not enclosed within the last larval skin as are muscoid Diptera such as the house-fly, and it superficially resembles a small asilid pupa.

At Galena, Ill., September 22, 1917, this fly was very abundant on the flowers of common roadside Helianthus, and a spider (*Phidippus audax* Hentz, det. C. R. Shoemaker) was seen to capture one of the flies as the latter alighted on the flowers.

Hairworms (Mermithidae)

Among the several thousand grubs reared at the Lafayette Laboratory but four have shown parasitism by hairworms. These worms are specifically indeterminable, from our material, but belong to the genus Mermis, and apparently we have two species: one from grubs collected at Pensacola, Fla., by R. N. Wilson, and the other from grubs collected at Oakland, Md., by W. E. Pennington. The Florida grubs, collected March 1, 1915, were received at Lafayette March 3, and placed in individual 1-ounce tin boxes. March 16 one grub was dead and found to be infested with Mermis, and ten days later a second dead and blackened grub was noticed, and Mermis infestation was found to be the cause of its death. The worms were comparatively small, measuring about 6 inches in length, and several occurred in each grub. In the second case mentioned, one grub among a lot collected at Oakland, Md., November 10, 1915, and received at Lafayette a few days later, was found dead November 15 and infested with two worms of the genus Mermis. These were of cream-yellow color and noticeably larger than those infesting the Florida grubs, measuring 11.3 and 12.5 inches in length respectively (Pl. XI, Fig. 45). Dr. Henry Fox, of the Bureau of Entomology, also reared a mermithid from a Phyllophaga grub, obtained at Tappahannock, Va., May 1, 1915, the dead grub and worm being noticed July 13 of the same year. More recently (October 1, 1917), among a collection of white-grubs made by Mr. C. F. Turner at Lexington, Mich., September 26, 1917, we found one live grub infested with these worms, which were visible through the integument of the dorsum of the last abdominal segment. These were photographed (see Pl. XI, Fig. 43, 44) and the live specimens were sent to Dr. N. A. Cobb, who determined the parasite as a mermithid.

According to published observations Mermis has been recorded from a large number of insect hosts, and we have ourselves frequently obtained it from cutworms. The worms, on becoming mature, leave the host, their maturity being usually coincident with the death of the host, and remain in the soil probably for several months in a semi-quiescent condition, during which period the sexual organs are developed. Mois-

ture is necessary for the growth and development of the worms although it has been assumed that the eggs might bear more or less desiccation. The eggs of the species parasitic on white-grubs are no doubt laid in the soil and it is to be presumed that the worms enter the body of the grub after hatching in the soil, although it is likewise possible that infestation occurs from eggs or young larvae taken into the body with food.

A West Indian Grub-Parasite (Campsomeris dorsata Fabr.)

Mr. D. L. Van Dine has reported *Campsomeris dorsata* as a parasite of a white grub in Porto Rico (77 and 78), and more recently Mr. W. Nowell has given an extensive account of this species (53) as a parasite of *Ligyrus tumulosus* Burm., which may have been the grub referred to by Van Dine. Whether it may also be a parasite of Phyllophaga or Phytalis grubs is not known, but Van Dine's record seems to justify mention of it as a possibility. *Ligyrus tumulosus* larvae live in manure and in soil rich in decaying matter, and the wasp in oviposition completely paralyzes the grub and then lays an egg on the under surface of the body, the egg being deposited on end and at right angles to the axis of the body. The green June-beetle [*Cotinus* (*Allorhina*) *nitida*] has similar habits, and according to our observations its common parasite (*Scolia dubia* Say) attacks the grub and oviposits almost exactly as does *C. dorsata*. The wasps of Campsomeris are like Elis adults in frequenting flowers, and in the sleeping habits of the males.

Predaceous insect-enemies of larva

Robber-flies (Asilidae)

The larvae of several species of robber-flies (Asilidae) are predaceous on Phyllophaga grubs, and doubtless many other species of this group of flies will be found similarly active and much more beneficial in destroying underground insects than has been supposed.

The adult robber-flies are more or less beneficial in that they prey upon other insects, and we have seen one species (*Proctacanthus milbertii*) capture and destroy such active and hard-backed beetles as tiger-beetles (*Cicindela 12-guttata* Dej.). They are often considered harmful and are frequently referred to as "bee-killers" because of their habit of catching honey-bees.

Larvae of Asilidae belonging to six genera (Promachus, Erax, Deromyia, Asilus, Ceraturgus, and Proctacanthus) are treated in the following pages as actual, probable, or possible predaceous enemies of white-grubs, the last two classes being included mainly for the benefit of other workers who may have opportunity for further observation of their habits.

Promachus vertebratus Say

This important enemy of white-grubs is known to occur in Michigan, Indiana, Wisconsin, Illinois, Iowa, Minnesota, South Dakota, and Washington.

According to our observations the larva of *P. vertebratus* is the most beneficial of the asilids known to attack white-grubs. It is very common in certain parts of Wisconsin and Michigan where the common white-grub is a serious pest. The writer has several times seen the larva of this species attacking grubs in the field, most frequently in the summer or early fall, when the grubs have become more or less inactive and have made cells preparatory to pupation. It makes a small entrance-hole into the cell and through this attacks the grub, withdrawing if necessary to escape its mandibles. After it has weakened the grub, or if this is in the inactive prepupal or pupal stage, the predator may enter the cell and leisurely consume its host. In the summer and fall of 1914 we found large numbers of the empty pupal exuviae of this fly protruding half their length or more from the ground in fields at Baraboo

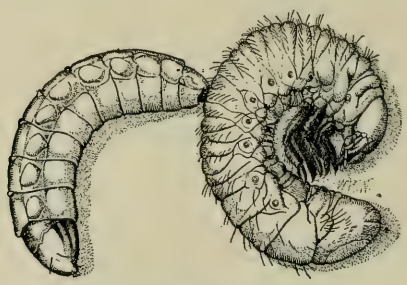

Fig. 20. *Promachus vertebratus* Say, larva attacking a white-grub.

and Madison, Wis., and at Richland, Mich., where grubs had been destructive in 1912 and the adult beetles of that brood had issued in the spring of 1914.

The life cycle has not been completely worked out, but from the facts that we have kept larvae in confinement for two years and that larvae of one size and pupal exuviae are found common in the same locality only every three years, it is probable that the cycle is three years, as Dr. Felt has found to be the case with *P. fitchii*. The larva is pure creamy-white, smooth, cylindrical, and tapering at the extremities. It very closely resembles the larva of Erax, and is shown in Figure 20. In feeding, it punctures the host with its sharp mandibles and, inserting its head in the small opening, sucks the body fluids. This and the other

asilid larvae differ noticeably from tabanid larvae in their feeding habits, the latter using their mandibles to tear the skin of the host and being exceedingly quick in their operations, while the asilids are slower in their movements and pierce their host by a puncture rather than by a cut or tear. The pupal form, and especially the brown chitinized spines and the stigmal spots, can be seen beneath the larval skin several hours

FIG. 21. *Promachus vertebratus* Say, pupa.

before pupation actually takes place. As the larval skin splits the pupa rapidly emerges, requiring less than a minute and a half to complete its exit. The head and body segments of the pupa are well armed with rigid spines (Fig. 21) which it uses to advantage in pushing itself to the surface of the soil just before the emergence of the imago. Pupation occurs, according to our records, from May 26 to July 18, and the adults issue from June 15 to August 18, the pupal period varying from 19 days, in rare instances, to 39 days, with an average from 55 examples of 32.+

FIG. 22. *Promachus vertebratus* Say, male.

days. Of the 59 adults reared and recorded as to sex, 29 were males and 30 females. The fly is very characteristically shown in Figure 22 and in Plate VII, Figure 26. The female lays its whitish, elliptical eggs in fall in cracks in the soil or in little earthen cavities which the female makes, usually several eggs being laid together. The larvae upon hatching search the soil for food, probably feeding at first on small

soft-bodied insects and possibly also on earthworms. We have no record of the number of grubs which a single *vertebratus* larva may destroy but it is doubtless several, possibly many, and it undoubtedly ranks as one of the most important natural enemies of the common white-grub.

Promachus fitchii O. S.

According to Aldrich's catalogue (1) this species has been recorded as occurring in Missouri, Kansas, Nebraska, Florida, and Connecticut, and we have reared it from larvae collected in the grub-infested areas near Richland, Mich., and Madison, Wis. The larva of *P. fitchii* was first reported as predaceous on grubs by Dr. E. P. Felt (18) who found it very abundant in fields heavily infested with white-grubs in New York, in some cases outnumbering the grubs. According to Dr. Felt's observations the larvae live in the ground at least two years, and it is believed that they have a three-year life cycle—which would correspond exactly with the length of the life cycle of the more injurious species of Phyllophaga in New York—a very important factor where only one destructive brood occurs every three years. There is little doubt from Dr. Felt's notes that this larva is as destructive to grubs in New York as is *P. vertebratus* in the central states.

According to our rearing records pupation occurs usually in June, although occasionally in May, and in every case the pupal period was almost exactly 30 days in length.

We are unable to distinguish the larvae of *fitchii* from those of *vertebratus* although the mature larvae of the latter are much the larger. The pupae are likewise very similar, but are separable according to Mr. J. R. Malloch (48). The adult of *fitchii* (Pl. VII, Fig. 27) is smaller than that of *vertebratus* and quite unlike it in appearance, the body of the former being covered, sparsely in parts, with golden hair.

Promachus bastardii Macq.

This species, which has not been seen by us, occurs in the Eastern States, and Mr. H. E. Smith states that the larvae are predaceous on Phyllophaga grubs in confinement cages. From this observation and from the known habits of the closely related species already mentioned, there is little doubt that *P. bastardii* attacks grubs under normal field-conditions.

Erax maculatus Macq.

(Syn. *E. interruptus* Macq., and *E. lateralis* Macq.)

Of the several species of Erax known to attack white-grubs, *maculatus* is the most common and beneficial. While following the plow near Greenwood, Miss., in March and April, 1914, Mr. H. E. Smith found many asilid larvae, the fields being in all cases infested with white-grubs to a greater or less degree; and in one or two instances the larvae were seen feeding on grubs. In confinement the larvae, which were believed to be of a single species, readily attacked grubs, usually puncturing the host on the dorsum near the head, but sometimes at

other points. Frequently they partially entered the opening thus made, all the while sucking the body fluids, sometimes feeding until nothing but the shriveled grub-skin remained. Several adults issued, all prior to August 21, 1914, but only one was preserved. This proved to be *E. maculatus*. A larva of this species which we obtained December 11, 1915, at Louisville, Ky., in sod ground heavily infested with Phyllophaga and Cotinus (Allorhina) grubs, pupated July 29—August 3, 1916, and the adult issued September 2. Mr. George G. Ainslie collected three larvae of this species while following a plow at Fellsmere, Fla., March 25, 1914, and placed them all in one box. When examined a month later only one remained, the others having apparently been killed and eaten by the survivor. This larva, which was received at the Lafayette Laboratory May 1, issued as an adult August 6, 1914. The larva (Fig. 23) of this species has been previously recorded by E. S. G. Titus (73) as predaceous on Ligyrus grubs in Louisiana. It attacks a grub as does

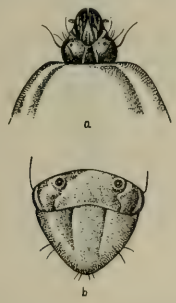

FIG. 23. Head *(a)* and anal segment *(b)* of *Erax maculatus* Macq., larva.

Promachus vertebratus, which is shown in Figure 20 in its typical position when attacking a grub.

From our data the life cycle appears to be one year, the winter always being passed in the larval stage, pupation occurring in July and August, and the adult fly (Fig. 24) issuing during August and early September.

The species is distributed from Pennsylvania to Central America, but seems to be more typically a species of the southern United States.

According to Titus (73), the adults of *E. maculatus* are predaceous on adult tabanids the larvae of which are predaceous on white-grubs.

ERAX AESTUANS Linn.

This species is included as a possible enemy of white-grubs from the fact that it was collected in a field infested with them and does attack Phyllophaga grubs in confinement. A single specimen was reared by

us from a larva received from Mr. G. G. Becker, obtained at Hot Springs, Ark., August 19, 1916. It pupated September 7 and issued as an adult October 22, 1916.

FIG. 24. *Erax maculatus* Macq., female.

ERAX CINERASCENS Bellardi
(Syn. *E. albibarbis* Macq.)

Mr. E. G. Kelly reared two adults of this species from larvae collected at Wellington, Kan., March 11, 1911, in fields infested by white-grubs. The larvae pupated between May 6 and 19, 1911, and adults issued about June 11. No evidence of their predaceous habits was obtained. We have also reared this species from a larva obtained by the writer September 29, 1916, in a field heavily infested by grubs at Rockton, Ill. The larva pupated between May 31 and June 7, 1917, and issued as an adult July 7, 1917.

DEROMYIA WINTHEMI Wied.

June 28, 1915, Dr. Henry Fox, while following a plow in a wheat stubble field at Tappahannock, Va., found a larva of this species "crawling over and apparently feeding on a Lachnosterna pupa." The larva

and pupa were placed together in a tin-box cage, and July 3 he saw the maggot feeding on the pupa. By July 6 nothing but the shriveled pupal skin of the grub remained and the larva appeared to be noticeably larger. It pupated previous to July 16, and the adult which issued between August 6 and 9 was determined by W. R. Walton as *Deromyia winthemi* (Pl. VIII, Fig. 31). Dr. Fox also reared this asilid from a pupa found in the soil at Tappahannock, Va., June 28, 1915, the adult issuing July 16, 1915.

Deromyia discolor Loew

Mr. Harrison E. Smith reared this species at Wellington, Kan., July 1, 1913, from a larva picked up behind the plow March 11, 1913, and Mr. J. A. Hyslop collected larvae behind the plow at Wolfsville, Md., May 2, 1913, from which he obtained pupae June 13 and 14 and two adults of D. *discolor* July 10 and 11, respectively. Aside from the fact that the fields were infested with white-grubs, there is no evidence that they were predaceous.

Deromyia umbrina Loew

Although we have no positive proof that this or the preceding species is predaceous on white-grubs, the fact that they are found in fields infested with grubs and the further fact that the very closely related

Fig. 25. *Deromyia umbrina* Loew, eggs, much enlarged.

species *D. winthemi* is known to attack them are indicative of their habits, and the notes herewith given seem pertinent.

A male and female *D. umbrina* collected at Lafayette, Ind., by Mr. R. J. Kewley, were placed in a chimney cage at 6:00 p. m., August 1, 1914, and by 3:30 p. m., August 4, 93 eggs were laid, the female dying the following day. The eggs were laid singly or in groups of 2 to 13, a few on the surface, but most of them in the soil at various depths up to ⅜ inch, the majority about ¼ inch deep. Some were placed in cracks in the dirt, and others in little cavities made by the female. The egg

is cream-colored, elliptical, slightly curved, 1.8 to 1.9 mm. in length by .8 mm. in width (Fig. 25, and Pl. IX, Fig. 38). The eggs hatched between 1:00 p. m. August 11 and 1:00 p. m. August 12, but none of the larvae were reared to maturity.

Asilus paropus Walk.

We have reared this species from larvae collected by the writer at Montford, Wis., October 3, 1914, in a field heavily infested by white-grubs, obtaining from the larvae thus collected 3 adults which issued June 9, 12, and 26, 1915, respectively; also from a larva taken at Lancaster, Wis., September 27, 1916, which pupated between May 24 and 31, 1917, and issued as an adult June 22, 1917. Although the reared specimens were not noticed feeding on grubs in the field, another specimen, supposed to be of the same species, was actually seen attacking a grub. This species has also been reared at this station from a larva obtained by Mr. A. F. Satterthwait in a grub-infested field at North Lima, Ohio, October 27, 1914, the adult in this instance issuing June 14, 1915. Mr. H. E. Smith has seen larvae of this species attack grubs in confinement, but, because of their small size, he believes they are more actively predaceous on smaller larvae, such as Anomala and Macrodactylus.

The life history of *A. paropus* is unknown, although it probably does not vary greatly from that of Promachus. The pupal stage, according to our observations, varies in length from 17 to 28 days, the adult, a small, slender fly, issuing in June.

The species is sparsely but generally distributed in the northern United States east of the Mississippi.

Asilus lecythus Walk.

We are not familiar with this species, which resembles *A. paropus*, but Mr. H. E. Smith reports it, in a letter, as predaceous on Phyllophaga grubs in confinement. He believes, however, that like *A. paropus* it is more often predaceous on smaller grubs of the genera Anomala and Macrodactylus.

Ceraturgus cruciatus Say

Our collection records show that the larva of this species occurs in fields heavily infested with white-grubs. One larva taken by C. F. Turner at Richland, Mich., April 18, 1917, pupated between May 3 and 10 and issued as an adult June 5, 1917.

Proctacanthus milbertii Macq.

The larva of this rather common Proctacanthus has not been seen attacking white-grubs but has been taken in fields heavily infested with them at Richland, Mich., by C. F. Turner, and at New Carlisle, Ind., by the writer. At the former place it was found in company with grubs of *Promachus vertebratus*. Our rather meager data indicate that it has a two- or three-year cycle, the larva pupating in July (July 13–23 according to our records), and the adults issuing about six weeks later (August 24 to September 6).

Coenomyia pallida Say

According to J. R. Malloch (49) the larva of *Coenomyia pallida* Say (=*ferruginea*, American authors) has been seen to feed on white-grubs in confinement. This larva was taken in a field near Chicago where grubs were common, and another at DuQuoin, Ill., "in company with larvae of Asilidae and probably fed also upon white-grubs."

Horse-flies (Tabanidae)

Two species of tabanid larvae (*Tabanus atratus* Fabr. and *T. sulcifrons* Macq.) are predaceous on Phyllophaga grubs, and further researches will no doubt show the like for other species.

The Autumn Horse-fly (Tabanus sulcifrons Macq.)

T. sulcifrons seems to be commoner than *T. atratus*. It has been reared from larvae collected in plow furrows at Greenwood, Miss., by Mr. J. M. Langston in February, March, and April, 1916. Some of these larvae pupated at the Lafayette Laboratory between August 7 and September 4, adults issuing August 23 to September 27, while others passed the winter in the larval stage. The length of the larval stage was 16 days for those pupating in August to 23 days for those pupating the first of September. The length of the life cycle probably is normally one year, but no doubt scarcity of food or unfavorable soil conditions may prolong this period, as is indicated in our experiments. Larvae apparently belonging to this species but which died before maturing,

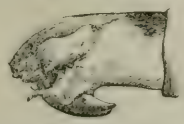

Fig. 26. *Tabanus sulcifrons* Macq., head of larva, showing sharp mandibles extruded.

were collected in plow furrows by Mr. E. G. Kelly at Wellington, Kan. Others were received from Mr. R. J. Kewley, who collected them while following the plow at College Park, Md., April 20, 1916. These continued as larvae until fall of the following year, pupating in August, 1917, and issuing as adults nearly a month thereafter. We also reared a single adult from a larva taken by G. G. Ainslie June 24, 1914, at Caney Springs, Tenn., the larva pupating between August 18 and 24 and the adult issuing September 14, 1914.

In all cases the larvae were collected in fields containing white-grubs, and their predaceous activities in relation to Phyllophaga and Cyclocephala grubs in confinement were conclusively shown. On coming into contact with the soft body of the grub the larva thrusts its mandibles into the skin, and into the opening thus made the head is inserted, and the body fluids are consumed. The action of the mandibles is very

peculiar and interesting. They are quite sharp, strong, slightly curved, and carried in a groove along the dorsal lateral side of the head when not in use. When in action they are rapidly thrust outwards and downwards (Fig. 26), the two generally working in unison and literally tearing the skin of the prey. Sometimes this operation is repeated several times and at different points on the body of the grub before any attempt at feeding is made. The writer has had his hand so severely punctured by the mandibles that itching or stinging lasted for several hours. In our

Fig. 27. *Tabanus sulcifrons* Macq., larva.

tin boxes the host grub sometimes prepared a cell, and the tabanid larva often made an entrance to the cell just large enough for its head and the fore part of its body, thus enabling it to withdraw, if necessary, to a safe distance from the grub. This strategy is also frequently adopted by asilid larvae. The Tabanus larvae can crawl about and penetrate the earth quite freely. They prefer moist places. They no doubt feed on various soft-bodied underground insects, and probably on earthworms also. This species and *T. atratus* can pass long periods without food—a capacity frequent among predaceous larvae living under similar conditions.

The adult is one of the common horse-flies and is often so abundant as to be a serious stock pest. It is distributed from New Jersey to Louisiana and Missouri. It is of large size, varying in length from 17 to 20 mm.; the large compound eyes are typical of the family; the under surface of the thorax is densely covered with a grayish pubescence, the upper surface with alternate black and grayish brown longitudinal mark-

Fig. 28. *Tabanus atratus* Fabr., larva.

ings; the dorsum of the abdomen is reddish brown, with yellowish white triangles on segments two to five; the wings are transparent, with certain areas of the veins margined with brown (Pl. IX, Fig. 34, 35). The eggs have not been described, but they are probably dull-colored and laid in masses like those of related species. The larva (Fig. 27) of this species, which measures about 30 mm. in length when full-grown, is glossy, semitransparent white with delicate, almost microscopic, longi-

tudinal striae. By these characters alone it is readily distinguished from the larva of *T. atratus,* which is marked with black (Fig. 28), and from the asilid larvae Erax and Promachus, which are waxy white or cream-color. Likewise the anal end of Tabanus bears a retractile fleshy protuberance or breathing tube (Fig. 29), and each abdominal segment bears six ventrally placed fleshy tubercles, the upper one on each side along the lateral line being the most conspicuous, and those on the last

FIG. 29. *Tabanus sulcifrons* Macq., anal end of larva.

two or three segments only faintly indicated. The asilid larvae lack these characters, the anal end being more or less pointed and the body smooth. The chitinous head is elongate and slender, brownish, and freely retractile (Fig. 26). The dull brown pupa (Pl. IX, Fig. 36) is slender, rather uniform in thickness throughout its entire length, curved, and is not armed with conspicuous spines as are the asilid pupae. The reader is referred to papers by Hine (36,37,38) and Hart (34) for more complete descriptions of this and the following species, and for particulars concerning their habits.

THE BLACK HORSE-FLY (TABANUS ATRATUS Fabr.)

Our observations on the habits and activities of this species are confined to one rearing record made from a larva obtained by Mr. A. F. Satterthwait near Linton, Ind., May 3, 1916. The larva was found along the drainage-ditch edge of a corn field where acute injury by wireworms and cutworms occurred in 1914. The tract in which this larva was found is a reclaimed swamp, covered with water much of the time until a few years ago and only the past season or two sufficiently drained for cultivation. The larva was placed in an ounce tin-box and there freely attacked and ate grubs of Phyllophaga and Cyclocephala. It pupated between August 24 and 29 and the mature fly issued September 11, 1916. Its feeding habits differed in no way from those described for *sulcifrons.*

The adult (Pl. VIII, Fig. 32; Pl. IX, Fig. 33) is one of the commoner species of horse-flies, known as the black horse-fly or breeze-fly, and is distributed from southern Canada to Mexico, east of the Rocky Mountains. It is conspicuous because of its very large size, measuring about 24 mm. in length. The large eyes are typical of the family, the thorax and abdomen are black and covered with a thin whitish bloom, and the wings are black at the base to dusky or brownish transparent at the apex. According to Mr. Chas. A. Hart, who carefully described the various stages (34), the eggs are dark brown, subcylindrical, about

2.5 mm. long, with the surface minutely rugose. They are laid in masses (as illustrated in Plate IX, Figure 37, single masses containing as many as 500 eggs) on rushes and the like over water or wet ground. The larva is larger than that of the species just described, and at the connection of each segment is a broad blackish band which widens on the sides to form a broken lateral longitudinal blackish line. Otherwise it resembles *T. sulcifrons*. It is well illustrated by Figure 28. The pupa is similar to that of *sulcifrons* but is slightly larger (Pl. VIII, Fig. 32).

According to Walsh and other authors this species is semiaquatic and feeds on water-snails, and probably also on various soft-bodied insects and earthworms.

Mr. Hart obtained a hymenopterous parasite (*Phanurus tabanivorus* Ashm.) from the eggs of *T. atratus* (Pl. IX, Fig. 37, and Pl. X, Fig. 39) and the same parasite has been reared from this host in Ohio and Louisiana by Prof. J. S. Hine (38). Another parasite, obtained by Mr. F. C. Bishopp from tabanid eggs collected in Texas, has been recently described by A. A. Girault as *Phanurus emersoni* (31). These two species of Phanurus are the only parasites known to attack the tabanids in any stage.

Coleoptera (Carabidae)

Carabid larvae are always to be found in abundance in fields which are being plowed, and occasionally they have been seen in unusual abundance in those heavily infested with white-grubs. While the evidence

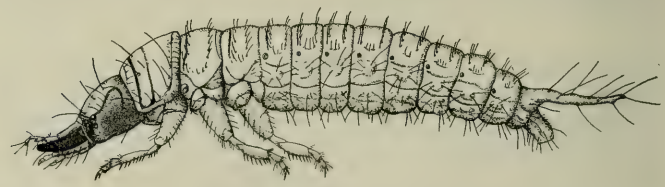

Fig. 29a. *Harpalus pennsylvanicus* Dej., larva, much enlarged.

in their favor in these cases is largely circumstantial, it is very probable that they are often predaceous on grubs, and much more beneficial than at present supposed.

While following the plow at Victoria, Texas, February 18, 1916, Mr. J. D. Mitchell found carabid larvae abundant in a grub-infested field; in fact they were nearly twice as numerous as the grubs, and the adults which we reared from the larvae sent to us, proved to be our common *Harpalus pennsylvanicus* Dej. (Schwarz det.). In our underground breeding-cages larvae and adults of *H. pennsylvanicus* (Pl. VII, Fig. 28) and Amara sp. have been found abundant, with evidence of their predaceous activities, and in the cages it appeared that the adult beetles as well as the larvae (Fig. 29a) attack the grubs. In the field this

species is the most frequent and doubtless the most beneficial of all the carabids, although we also find the larvae of *H. caliginosus* Fabr. quite common in grub-infested fields.

An interesting observation on the predaceous habits of these larvae was made by Mr. H. E. Smith at Wellington, Kan., April 4, 1913. A carabid larva picked up behind the plow and placed with a Phyllophaga grub immediately attacked it, piercing the skin with its mandibles but not tearing it, making only a small opening through which the body fluids were obtained. The grub thus attacked died in about three hours, after most of the body fluids had been consumed. The carabid died before maturing.

The carabid adults, commonly termed ground-beetles, have been frequently observed feeding on adult May-beetles. Mr. C. M. Packard saw an adult *Calosoma calidum* Fabr. in the act of attacking a live May-beetle at Hagerstown, Md., April 21, 1914. The beetle worked its head beneath the elytron of its prey and bit into the soft part of the abdomen, a method usually practiced by these insects. Mr. Packard observed at the same time a *Harpalus caliginosus* eating the remains of a dead Phyllophaga, there being no proof, however, that it was responsible for the death of the beetle. Mr. W. L. Taliferrio saw at College Park, Md., May 8, 1893, a *C. calidum* feeding on the viscera of a live Phyllophaga adult through a hole in the abdomen, and the writer has made similar observations at Lafayette, Ind. We have also seen *Calosoma scrutator* Fabr. eating a live May-beetle beneath an electric light. Dr. Forbes (25) mentions finding a carabid beetle (*Chlaenius tomentosus* Say) clinging to a Phyllophaga beetle and feeding upon its viscera, partly drawn out of the wound, and Dr. Riley (60) saw *Calosoma lugubre* attacking May-beetles beneath street lights.

An interesting parasite of *Harpalus pennsylvanicus* (?) larvae was found by the writer at Mendon, Mich., September 11, 1916. In the field, which was being plowed, carabid larvae and adult *H. pennsylvanicus* (Schwarz det.) were exceedingly numerous, and two larvae were found parasitized by a hymenopteron. Both were rigid, as though attacked by an Isaria fungus, and to one the naked pupa of the parasite was attached. The other showed the parasite larva just issuing. The larva when mature, issues from the anal end of the host, and, remaining attached, it pupates as illustrated (Pl. XV, Fig. 61). The adult of this parasite was not obtained.

Miscellaneous Insects sometimes Predatory

Dr. Forbes (26) records an observation made by E. G. Kelly, who found three yellow coarctate meloid larvae with the remains of white-grubs attached, the natural supposition being that they had been feeding on the grubs; and this is quite probable since it is a well-known fact that meloid larvae, the immature stages of the destructive blister-beetles, feed on grasshoppers' eggs and the immature forms of certain other insects.

Ants can not be considered predaceous enemies of white-grubs, but in our cages it is evident that they have been responsible for the death of grubs and pupae. It is doubtful if healthy grubs are ever attacked by them under normal conditions, but we have seen them attacking grubs almost immediately after being exposed by removing a piece of infested sod. The ants in the cases mentioned above, were *Lasius niger* Linn., var. *americanus* Emery.

According to Mr. E. G. Smyth, Mr. T. H. Jones reared larvae of an elaterid (*Pyrophorus luminosus* Ill.) upon Phyllophaga larvae in confinement, and adults were taken from soil in a cane field in Porto Rico where the white-grubs had been present in numbers, the latter fact indicating that the predaceous activity observed by Mr. Jones in the cages is a normal habit of the larvae under field conditions. Mr. J. A. Hyslop has found these larvae similarly active toward white-grubs in tin-box cages.

Crickets may also prey upon white-grubs, as was noticed by the writer at Cascade, Iowa, September 24, 1917. While following the plow in a sod field heavily infested with the 1917 brood of grubs, two species of crickets (*Gryllus assimilis* Fabr. and *Nemobius fasciatus*, var. *vittatus* De G., Caudell det.) were seen to attack the young grubs as these were exposed by the plow. The crickets were quite numerous, the small Nemobius probably the more common, and after attacking the grub they would feed on the fluids issuing from the wounds.

Mites as Enemies of Phyllophaga Larvae

Mites, determined by Mr. Nathan Banks as *Rhizoglyphus phylloxerae* Riley, have frequently been found infesting grubs in the field and are a constant cause of trouble in our breeding cages. They firmly attach themselves to their host, and if not removed will frequently kill the grub. While we have never found them as destructive in the field as in our tin-box cages, nevertheless there is little doubt that they do sometimes weaken or even kill grubs under natural conditions (55). The same species has been collected on white-grubs by Mr. J. A. Hyslop at Hagerstown, Md., and by Dr. Henry Fox at Tappahannock, Va. It is widespread, our records showing its occurrence in the United States from Massachusetts to Texas. Its normal food appears to be decaying vegetable and animal matter.

A pale whitish species, *Tyroglyphus armipes* Bks. (Banks det.), was found infesting white-grubs collected at Austin, Tex.; and a third species attacking them, which Mr. Banks determined as Parasitus sp., was collected by Mr. C. N. Ainslie at Springville, Utah, and at Elk Point, S. Dak.

The adult May-beetles are also sometimes infested by mites, and specimens referred to Mr. Banks were determined as belonging to the family Parasitidae (Gamasidae) and to the genus Uropoda. All of the mites we have collected on May-beetles are in the nymphal migratory stages, in which they attach themselves to the beetles as a means of car-

riage, and are probably neither parasitic nor predaceous. When a suitable breeding ground is reached the mites drop and transform, and begin to feed on bacterial and fungous growths.

Parasites of the beetle

Ortalid Flies

(Pyrgota undata Wied. and P. valida Harris)

Our earliest record of *P. undata* as a parasite of Phyllophaga adults was made by Prof. F. M. Webster, who reared it in the spring of 1891 from beetles collected at Lafayette, Ind., and the first published record is that of Dr. Forbes in 1907 (26). *P. valida* was first reared and recorded by the writer in 1913 (15), and we have since reared it many times.

The life histories of the two species are substantially alike. The beetles are attacked only at night while they are feeding, or in flight, the Pyrgota fly alighting on the back of the beetle, which if feeding is

Fig. 30. *Pyrgota undata* Wied., female.

usually sufficiently disturbed to cause it to drop, at the same time spreading its wings to break the fall. The fly immediately takes advantage of this act to thrust its ovipositor through the exposed thin abdominal wall beneath the wing covers and to lay an egg in the abdomen. The abdomen and ovipositor of Pyrgota are admirably adapted to this act, the former being curved, with the tip hard and conical, and the ovipositor being a fleshy muscular organ of medium length with a sharp-pointed chitinous tip (Fig. 31).

The eggs are elliptical, measuring .05 mm. by 1.2 mm., and pure white (Fig. 32). Counts of eggs in the bodies of two specimens of *P. undata,* made May 29, 1913, gave 54 and 98 respectively. The length of the egg stage has never been determined by us, but it is probably only five or six days, since the beetles are killed by the maggots within ten days or two weeks after being attacked, and the average length of the egg and larval stages combined is about three weeks. Before succumbing to the attack of the parasitic larva the beetle enters the earth to a depth of two to six inches, and within the abdominal cavity of the host the larva pupates and remains as a puparium until the following spring. Occasionally some of the tachinid parasites issue in the summer of the same year in which they pupate, but this never occurs with Pyrgota, and we have never found more than one Pyrgota developing within the same host. Rarely the Pyrgota remains in the puparium stage over two winters. In one case a male *P. futilis* caged June 12, 1916, was found to contain a parasitic larva June 27, this larva forming the puparium

FIG. 31. *Pyrgota undata* Wied., ovipositor extruded.

FIG. 32. *Pyrgota undata* Wied., egg, much enlarged.

shortly thereafter, and although other parasites of the same species and from the same lot issued in the spring of 1917, one remained over the second winter and issued as an adult female *P. undata* May 11, 1918, about two years after it was first observed in the host. The larva (Fig. 33) is white and very robust, and in this respect might be likened to some of the larger nut-weevils. The puparia of the two species (Fig. 34, and Pl. X, Fig. 41) are quite distinct and readily recognized. They are alike in shape, being broadly ovate, noticeably thicker and broader at the rounded anal end, the anterior end being pointed, but differ in size, texture, and posterior spiracles. The puparium of *P undata* is the

larger of the two, averaging about 4.8 mm. at its widest point and 9.0 mm. in length, nearly smooth, and black with a slight silky luster. The posterior pair of spiracles are set a little above the median lateral line, one on each side of a small but prominent cavity which is encircled by a rugose ridge. *P. valida* is a smaller species, the puparium (Pl. X, Fig. 41) of which measures about 4.0 mm. at its widest point, and 7.5 mm. in length. It is dull black, coarsely punctate, being covered throughout with closely placed deep punctures. The spiracles are distant from the median lateral line and there is no trace of a cavity as described for *undata*. The adult flies are rather grotesque in appearance, being about as large as a medium-sized wasp, the head pointed at the apex and subtriangular or conical, with prominent eyes, the thorax of the usual size, and the abdomen slender at the base but broadening apically, and narrow-

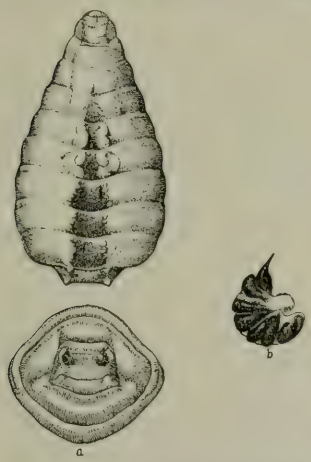

FIG. 33. *Pyrgota undata* Wied., larva; *a*, posterior end, showing posterior spiracles; *b*, one of the spiracles much enlarged.

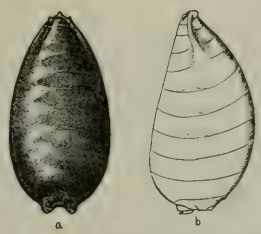

FIG. 34. *Pyrgota undata* Wied., puparium, *(a)* ventral and *(b)* lateral view.

ing again in the female to a conical tip. The body and legs of *undata* are brownish, and the wings, excepting the posterior margins, are of the same color (Fig. 30), while in *valida* the body and legs are blackish and the wings mottled with black (Pl. XI, Fig. 42).

Pyrgota undata appears to be the more common of the two species and has been recorded from such widely separated localities as Quebec, (Canada), New Jersey, and Kansas. We have reared it from nine species of Phyllophaga, namely, *P. bipartita, forcida* (=*arcuata*), *fra-*

terna, fusca, futilis (=*gibbosa*), *hirticula, ilicis, implicita,* and *vehemens,* collected from Illinois, Indiana, Missouri, Wisconsin, and Virginia, as follows: St. Louis, Mo. (Phil. Rau); Charlottesville, Va., (H. Fox and W. J. Phillips); and from Milford and Sheldon, Ill., Lafayette, Orleans, Princeton, and Vincennes, Ind., and Lancaster, Wis. (members of the Lafayette Station staff, including R. J. Kewley, D. G. Tower, A. F. Satterthwait, H. J. Hart, F. A. Fenton, S. L. Mason, and the writer). In addition we have found puparia of this species in the bodies of *P. hirtiventris* and *P. calceata* collected in 1914 at Pauls Valley and Shawnee, Okla., respectively, by Mr. W. E. Pennington, the parasitized beetles being among a lot which had previously been caged for eggs and later sent in for determination. An empty *undata* puparium was found in the body of a dead female *P. hirticula* picked up behind the plow by Mr. C. M. Packard at Hagerstown, Md. Other distribution records of *P. undata* in our files include Tempe, Ariz. (V. L. Wildermuth), Ithaca, N. Y., and Indianapolis, Ind. (H. Morrison), and New Haven, Conn., and Linglestown, Pa. (Champlain). The dates of emergence according to our 166 rearing records are May 8 to May 30, and in the field we find the species most common about May 20–24. Female beetles are much more frequently parasitized than males, and there appears to be some evidence that male flies are more frequently produced in the smaller species of beetles; in other words, the supply of food appears to have an influence in determining sex.

Pyrgota valida was bred from thirteen species of May-beetles, namely, *P. anxia* (=*dubia*), *balia, calceata, crassissima, crenulata, fervida* (=*arcuata*), *fusca, futilis,* (=*gibbosa*), *hirticula, implicita, inversa, rugosa,* and *tristis* collected as follows: Strathroy and Wilton Grove, Ontario, Can. (collected by H. G. Crawford), Manhattan, Kan. (J. W. McColloch), Wakeman, O. (W. B. Hall), and Sheldon, Ill., Lafayette and Orleans, Ind., Battle Creek, Farmington, Holland, Imlay City, and Port Huron, Mich., and College Station, Tex. (members of Lafayette Station staff, including D. G. Tower, H. J. Hart, A. F. Satterthwait, R. J. Kewley, F. A. Fenton, S. L. Mason, and the writer). In addition a puparium of this species was found in the body of a female *P. calceata* obtained at Shawnee, Okla., in 1914 by W. E. Pennington. In literature it has been recorded from New York to Illinois, and Mr. E. G. Kelly has collected the adult at Wellington, Kansas. The adult of *valida* emerged, according to our 95 cage records, much earlier than *undata,* that is from April 23 to June 5, and out-of-doors it is found most often early in May, although we have taken it at Lafayette, Ind., as late as May 25, while collecting beetles from trees at night. *P. valida,* as in the case of *undata,* has a one-year life cycle, only one larva develops in a beetle, and females seem to be more readily subject to attack than males, although this tendency is more marked in our *undata* records.

Both species frequent trees at night where the beetles are feeding, and both sexes are often attracted to electric lights, sometimes in very conspicuous numbers.

These species are not as abundant nor apparently as wide-spread as our common tachinid (*Cryptomeigenia theutis*), but in some sections where they occur in sufficient numbers they are undoubtedly beneficial to a marked degree, especially as they most frequently attack the female beetles. Although these may lay a few eggs after being parasitized, our studies up to the present time indicate this to be the exception rather than the rule.

We have never reared a parasite of Pyrgota, but Mr. E. G. Smyth has done so and has sent us two examples of the parasite, which were determined by Mr. S. A. Rohwer as a new genus and new species in Bethylidae. Mr. Smyth reared these from a *Pyrgota undata* puparium found in Illinois in 1914 by Mr. G. N. Wolcott, and writes that a number of the parasites issued from a single puparium.

Tachinid Flies

In our studies three species of tachinid flies (*Cryptomeigenia theutis, Eutrixa exile, and Biomyia lachnosternae*) have been reared from May-beetles, and of these *C. theutis* is much the most common and wide-spread and seems to be the most beneficial of the parasites attacking the Phyllophaga adult. The three species can be readily distinguished in the adult and pupal stages by characters shown in the accompanying illustrations of the flies and the posterior spiracles of the larvae or puparia (Fig. 35, 36, and 41-43). Two other species (*C. aurifacies* and *Eutrixoides jonesii*), which occur in Porto Rico, are briefly treated.

Cryptomeigenia theutis Walk.

The first published record of the parasitic habits of this species is that of Coquillett (13), who reports it as having been reared by Theo. Pergande from an adult *Phyllophaga inversa* taken at Washington, D. C., May, 1892, the fly issuing Mar. 23, 1893. The species occurs generally throughout the northern states east of the Rocky Mountains, and its distribution, according to published records and our own studies, includes Toronto and Montreal, Canada; New Hampshire, Massachusetts, New York, New Jersey, District of Columbia, Ohio, Indiana, Michigan, Wisconsin, Illinois, Kansas, Mississippi, Virginia, and Tennessee; and Mr. Norman Criddle writes Jan. 10, 1918, that he has reared it from May-beetles collected in Manitoba, Canada.

We have reared *theutis* only from Phyllophaga, including the species *drakii* (=*grandis*), *fervida* (=*arcuata*), *fraterna, fusca, futilis* (=*gibbosa*), *hirticula, ilicis, implicita, inversa, micans, rugosa, tristis,* and *vehemens*, but the writer once observed it in the act of laying an egg on an adult Diplotaxis, and it is not unlikely that further study will show it to be parasitic on certain of the larger Diplotaxis and beetles of related genera which feed on tree foliage at night. The fly (Fig. 35), which is about the size of the common house-fly and superficially resembles it, is frequently seen resting on tree foliage at night. At Lafayette, Ind., we find it throughout the month of May, sometimes earlier,

FIG. 35. *Cryptomeigenia theutis* Walk., male.

FIG. 36. *Cryptomeigenia theutis* Walk., larva; *a*, anal end, showing posterior spiracles; *b*, posterior spiracles much enlarged.

and frequently during the month of June. In the act of oviposition the fly stealthily crawls onto the beetle while the latter is feeding or copulating at night and proceeds to lay one or more eggs, which it fastens to the body of the beetle by means of a glutinous secretion. The eggs (Fig. 37) are light brown, oval, measuring .36 mm. by .66 mm. They are frequently laid on the abdomen, usually at the side and near the edge of the elytron (Pl. X, Fig. 40) or they may even be slipped beneath the wing cover. They are sometimes laid on the hard parts of the body, such as the elytra and thorax, but it is questionable whether larvae hatching from eggs thus deposited are able to enter the body of the host. The larvae (Fig. 36) enter the abdominal cavity of the beetle and devour the fatty tissues, finally attacking the vital organs and thus killing the host. Before succumbing to the attacks of the parasitic larvae, in fact several days before death, the beetle almost invariably enters the soil to a depth of several inches, sometimes 6 or 8, the larvae pupating within the body cavity and remaining there as a rule until spring of the following year.

FIG. 37. *Cryptomeigenia theutis* Walk., eggs, much enlarged.

This species is the most frequent beetle parasite according to our observations, which include over 850 rearing records from the following localities: Manhattan, Kan. (J. W. McColloch and W. P. Hayes), Greenwood, Miss. (J. M. Langston), Wakeman, O. (W. B. Hall), Clarksville, Tenn. (H. Fox and P. Wyatt), Richmond, Va. (T. S. Herbert), Tappahannock, Va. (H. Fox), Milford and Sheldon, Ill., Akron, Huntingburg, Lafayette, Orleans, Princeton, and Vincennes, Ind., Battle Creek, East Leroy, Farmington, Imlay City, Mendon, Port Huron, and Richland, Mich., Napoleon and Swanton, O., and Trout Lake, Wis. (members of Lafayette Station staff, including R. J. Kewley, D. G. Tower, A. F. Satterthwait, S. L. Mason, F. A. Fenton, H. J. Hart, C. F. Turner, and the writer). The names in parenthesis indicate the collectors, who greatly helped the investigation by sending in specimens of

live May-beetles. In some cases the flies issued the year they killed the beetles, but most of those forming puparia in the spring of one year did not issue until the spring of the following year. From this and other data it is certain that under natural conditions the flies normally have a one-year life-cycle. In our cage experiments flies began to issue soon after the cages were removed from their winter quarters, that is about April 20, and continued to issue until early in May. These dates are somewhat earlier than is normal out-of-doors, the first emergence of flies usually being coincident with or shortly after beetle emergence, which in the latitude of Lafayette is, as a rule, the last few days in April. It would appear that both sexes of beetles are attacked indifferently, since the number of male and female beetles from which the flies are reared is almost exactly the same. From one to seven larvae may develop in a single host, although we have never reared to the adult more than five from one beetle, and the average of the 134 examples observed in 1916 is 2.8 larvae to each beetle.

C. theutis seems to be parasitized by a very interesting hymenopterous parasite (*Lepidopria aberrans* Brues). At Hagerstown, Md., August 15, 1913, Mr. J. A. Hyslop, of the Bureau of Entomology, found a dead female *Phyllophaga inversa* containing two dipterous puparia, which agreed with those of *C. theutis.* Each puparium showed two minute holes, and when opened one contained the shriveled remains of a fly and the other the fragments of an apterous hymenopteron which was determined and described by Mr. C. T. Brues as the above-mentioned species (10). We have occasionally found puparia showing minute holes, but have never found the parasite which was presumed to have made them.

Cryptomeigenia aurifacies Walton

This and the following species have been reported as parasites of Phyllophaga adults in Porto Rico but are not known to occur in the United States. *C. aurifacies* (Fig. 38, 39) was described and first recorded as a parasite in 1912 by Mr. W. R. Walton (80), and was later reported by Mr. D. L. Van Dine (78) as bred from beetles collected in several localities in Porto Rico. It is closely related to our common *C. theutis,* but may be distinguished from that species by the dorsal vittae of the thorax, which are distinctly velvety black, these markings being indistinct brownish in *theutis;* likewise the sides of the face of *aurifacies* are distinctly golden yellow pollinose, the face of *theutis* being gray.

Eutrixoides jonesii Walton

A second tachinid parasite, not known to occur in the United States, was bred from Phyllophaga adults in Porto Rico by Mr. T. H. Jones in 1912, and the species described by Mr. Walton in 1913 (81). Although closely related to our American May-beetle parasite, *Eutrixa exile,* it is distinguished, according to Mr. Walton, by the remarkable development of the ovipositor (Fig. 40), and in the male by its much narrower front and face.

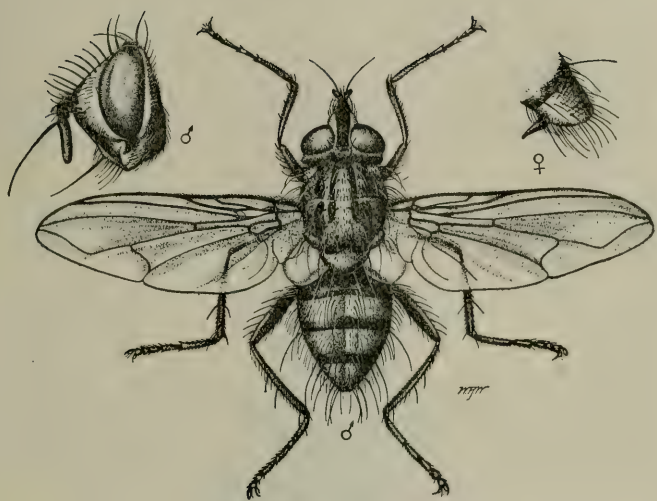

FIG. 38. *Cryptomeigenia aurifacies* Walt. (After Walton.)

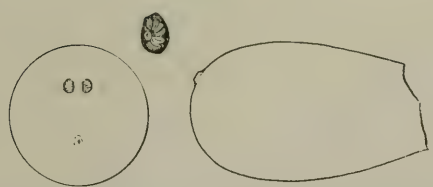

FIG. 39. *Cryptomeigenia aurifacies* Walt., puparium (anterior end missing), anal end, showing position of spiracles, and one of the spiracles more enlarged.

Eutrixa exile Coq.

This species (Fig. 41) was first reported as a May-beetle parasite in 1897 by D. W. Coquillett under the name *Eutrixa masuria* Walk. (13). The flies issued March 12, 16, and 23, 1895, from a *P. arcuata* adult obtained at Washington, D. C. It is almost as wide-spread as *Cryptomeigenia theutis*, the published records giving its distribution as Ontario, Canada; New Hampshire, New York, Maryland, District of Columbia, Virginia, Ohio, Indiana, Michigan, and Wisconsin. Our records show it to occur also in Mississippi, Missouri, and South Carolina. Although the species occurs more commonly in the Northern States, it seems to be less typically northern than *C. theutis*.

We have reared the species from fifteen species of Phyllophaga, namely, *P. anxia* (=*dubia*), *drakii* (=*grandis*), *fervida* (=*arcuata*), *fraterna, fusca, futilis* (=*gibbosa*), *hirticula, ilicis, implicita, profunda*

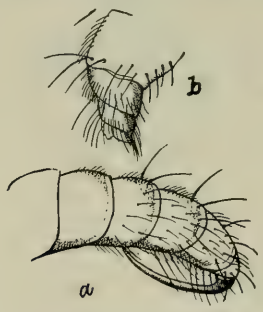

Fig. 40. Tip of abdomen *(a)* of *Eutrixoides jonessi* Walt., and *(b)* of *Eutrixa exile* Coq.

rugosa, tristis, vehemens, vilifrons, and new species *b*,* and from beetles representing 200 records and collected in twenty-four localities as follows: Strathroy and Wilton Grove, Ontario, Canada (beetles collected by H. G. Crawford); Starkville, Miss. (G. F. Arnold); Mt. Grove, Mo. (M. P. Somes); East Greenbush, N. Y. (E. P. Felt); Winfield Junction, L. I., N. Y. (Jay Sedgwick); Wakeman, O. (W. B. Hall); Charlottesville, Va. (W. J. Phillips and H. Fox); Richmond, Va. (T. S. Herbert); Sharps and Tappahannock, Va. (H. Fox); and from Akron, Lafayette, Orleans, Princeton, and Vincennes, Ind.; Adrian, Battle Creek, East Leroy, Farmington, Imlay City, and Port Huron, Mich.; Swanton, Ohio; and Platteville and Trout Lake, Wis. (members of the Lafayette Station staff). In addition, Mr. Philip Luginbill, of the Bureau of Entomology, reared it in 1913 from an adult *P. tristis* taken

* An undescribed species in author's collection.

at Columbia, S. C., and Mr. Rees Philpott reared two of the flies May 3, 1915, from a single Phyllophaga beetle found two days before in the soil at Delaware, Ohio.

We have not studied all the details of the general habits and life history of this species, but as far as known they agree with those of *C. theutis,* the fly being nocturnal and laying its eggs on the beetles while they are feeding or resting on tree foliage at night. Some of the flies issue the same season they parasitize the beetle, that is during July, about one month after puparia are observed, but this is probably due to the conditions referred to in the discussion of *C. theutis,* and in a natural

FIG. 41. *Eutrixa exile* Coq., male.

environment the life cycle is probably normally one year. In cages the flies begin to appear soon after they have been removed from the compost heap where they are kept during the winter months, but under normal out-of-door conditions emergence is coincident with the appearance of May-beetles or a little later, their first appearance usually being a few days or a week after that of *C. theutis.* Our records show that the male and female beetles are about equally attacked and that from one to eight larvae develop in a single host, the average for 183 examples being two to a beetle.

E. exile may be distinguished in the larval and pupal stages from other parasites of May-beetles by the characteristic posterior spiracles, illustrated in Figure 42

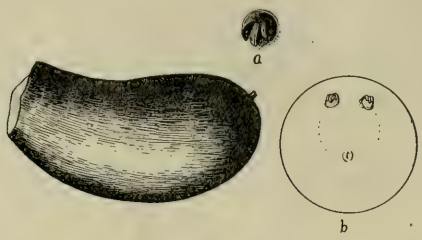

FIG. 42. *Eutrixa exile* Coq., puparium from which adult has issued; *a*, posterior spiracles, much enlarged; *b*, anal end, showing posterior position or posterior spiracles.

BIOMYIA LACHNOSTERNAE Towns.

Biomyia lachnosternae was first reared by the writer in 1905 from an adult *Phyllophaga crenulata* taken at Urbana, Ill., and was recorded by Dr. S. A. Forbes (26) as a species of *Viviana*. This was later described by Mr. C. H. T. Townsend as a new species under the name *V. lachnosternae* (75). The beetle referred to above was obtained July 15, laid three eggs after being placed in a flower-pot cage, and died about July 29, the fly (Fig. 43) issuing August 5, after the beetle had been pinned. We have also reared it from beetles collected in Mississippi, South Carolina, and Virginia, and it is apparently typically a member of the southern fauna.

In our rearing experiments we have bred this parasite from 89 beetles representing nine species of Phyllophaga, namely, *P. calceata, ephilda* (=*burmeisteri*), *forbesi, forsteri* (=*nova*), *luctuosa, prununcolina, quercus, vehemens,* and new species *b*. The beetles from which they were reared were collected at Agricultural College, Miss. (collected by students through the courtesy of Professor R. W. Harned), Greenwood, Miss. (collected by J. M. Langston); Gulfport, Miss. (C. C. Greer); Columbia, S. C. (Philip Luginbill); and Charlottesville and Tappahannock, Va. (H. Fox). It differs from the two preceding in that not more than one maggot normally develops in a single beetle, only one case having been observed in which as many as two flies came from the same host, and according to all our records the adults invariably issue within 45 days of the time when they were collected and caged. We have not studied the species under conditions occurring in the Southern States, its normal habitat, but the evidence at hand

indicates a second seasonal generation, and this is possible since adult Phyllophaga of one species or another are active in the Southern States from the latter part of March until the middle of August.

The species may prove to be an appreciable aid in the control of Phyllophaga in the Southern States.

FIG. 43. *Biomyia lachnosternae* Towns., male.

SARCOPHAGIDS, INCLUDING DOUBTFUL RECORDS

Several sarcophagids have been recorded in literature as parasitic on Phyllophaga adults, and we have occasionally reared them—and once an anthomyiid—in cages containing May-beetles, but in most cases it was plainly evident that the flies had hatched from maggots which fed only on the dead beetles. In all cases where these flies have been reared at the Lafayette Laboratory, the cages were covered with wire-screen, permitting larvae or eggs to be thrust into the cage through the meshes. Furthermore, all such rearing records were from cages containing large numbers of beetles confined for parasites, and the dead beetles and abundant excrement were no doubt attractive to the scavenger flies. It might be noted that the sarcophagid larvae invariably left the dead

beetles to pupate, which is never the case with the beetle parasites already treated. Of the eight sarcophagids briefly treated in this connection only the first four (*S. prohibita S. tuberosa*, var. *sarracenioides, S. cimbicis,* and *S.* new species) are probably true parasites of May-beetles. Like other sarcophagids they are active during the daytime, and each of the four was reared from a diurnal May-beetle.

Sarcophaga prohibita Ald.

We have only one rearing record of this species. In a lot of *Phyllophaga lanceolata* received at Lafayette, Ind., July 4, 1916, from J. W. McColloch and W. P. Hayes, and collected at Manhattan, Kan., three days previous, one male and one female beetle were dead July 6, each containing a dipterous larva. One fly issued July 25, 1916, but was destroyed in the mail before being determined. The other fly issued June 5, 1917, and was determined by Dr. Aldrich as his *prohibita*. From the facts that both beetle and fly are diurnal, that the beetles were alive when received at Lafayette, and that *prohibita* is not known to occur in Indiana but is more or less common in Kansas, it seems reasonably certain that this fly is a parasite of Phyllophaga.

Sarcophaga tuberosa Pand., var. sarracenioides Ald.

We have never observed this species, but Dr. J. M. Aldrich (2) records it on the authority of Mr. E. G. Kelly as having been reared from adult Phyllophaga. Mr. E. L. Barrett, of the U. S. Entomological Laboratory at Wellington, Kan., obtained a number of this species July 13, 1916, from a screen-covered cage containing adult *Phyllophaga lanceolata* collected June 9, 1916. The cage had been sifted July 10, at which time the puparia of this fly were found in the dirt. It is probable that this sarcophagid is a true parasite of the diurnal *lanceolata,* but it is evident from our present knowledge of the Sarcophagidae that it is possible for the flies to deposit their larvae through the wire screen, and this is especially likely when the cages contain large numbers of beetles, many of which die on the surface, the dead bodies together with the abundant excreta being attractive to female sarcophagids. This fly has been recorded as parasitic on several insects and has also been reared from human excrement, dead fish, etc. Its range is from Virginia to Washington and British Columbia on the west, and south to Texas and Arizona.

Sarcophaga cimbicis Towns.

This species was obtained from a screen cage containing *Phyllophaga lanceolata* by Mr. E. L. Barrett at Wellington, Kan., and was reared along with *S. tuberosa* var. *sarracenioides,* notes for which have just been given under that species heading. It is probably a true parasite of this diurnal May-beetle, but further exact experiments will be necessary to prove this beyond doubt. The species was originally reared from the willow sawfly (*Cimbex americana*), and no further records of its parasitic habits have been published to my knowledge, although it ap-

pears to be a rather common species with a range almost as extensive as that of *sarracenioides*.

SARCOPHAGA, n. sp. (Aldrich det.)

May 6, 1918, we received two pinned male *Phyllophaga farcta* from F. B. Paddock, which bore the label "Lometa, Texas, April 30, 1918". On receipt the abdomen of one beetle was found loose in the box, together with two sarcophagid larvae, one of which was immature and did not issue, the other issuing as an adult fly May 20. It was determined by Dr. Aldrich as a new species belonging, according to genital characters, to the group known to be parasites.

SARCOPHAGA HELICIS Towns.

S. helicis has been repeatedly reared from larvae and puparia from cages containing numbers of May-beetles caged for parasites, and the dying beetles were no doubt responsible for the attraction of *helicis* adults and their subsequent oviposition in the cage through the wire screen. Repeated unsuccessful attempts have been made to induce the flies to infest live beetles, and it might be mentioned in this connection that Mr. A. F. Satterthwait conducted at Lafayette, Ind., a number of experiments to ascertain whether the flies of this species would infest live army-worms (*Cirphis unipuncta*), all these experiments resulting negatively.

In 1893 Mr. C. H. T. Townsend (74) listed this species among a lot reared from Phyllophaga by Dr. Forbes, but there is no evidence that they were reared from live beetles. Dr. J. M. Aldrich (2) also records it as having been reared from Phyllophaga adults at Washington, D. C., in 1893, but he questioned this record and considered it as probably a scavenger. The writer believes there is no basis for regarding *S. helicis* as a parasite of Phyllophaga, but there is sufficient evidence to prove its scavenger habits.

SARCOPHAGA UTILIS Ald.

We have reared *S. utilis* from a dead *Pelidnota punctata* adult, from loose puparia in the soil of Phyllophaga cages, and in one instance from a larva found in the body of a dead female *P. implicita*. The beetles in the cage in the last-mentioned case were collected at Lafayette, Ind., June 21, 1915, and the dead *implicita* beetle containing the nearly full-grown larva of *S. utilis* was found July 2. The larva left the beetle and pupated in the soil several days after, and the adult fly issued August 12. We have also reared it from dead *Cotinus nitida* adults, in which case it was almost certainly a scavenger, and Mr. W. R. Walton reared it from a dead *Geotrupes splendidus* (2).

The possibility of this species being parasitic on Phyllophaga is very much to be doubted in the face of the evidence at hand.

SARCOPHAGA FALCULATA Pand.

This fly was obtained by E. G. Kelly and J. S. Wade from a cage containing May-beetles collected at Charleston, Mo., by Vernon King,

but there is no evidence that they were reared from live beetles, and it is hardly possible that they were. This species has been reared, according to Aldrich (2), from decaying meat.

Fannia canicularis Linn.

This interesting little fly, frequently found in houses and therefore termed the little house-fly, was reared from a female *Phyllophaga vehemens* obtained by J. M. Langston at Greenwood, Miss. The live beetles were collected April 24, 1915, and received at the Lafayette Laboratory April 28. The cage was examined May 4, at which time the dead beetles were discarded, and when again examined, May 28, one beetle was found to contain a dipterous puparium, the adult fly, determined by Dr. Aldrich as *F. canicularis*, issuing July 20 of the same year. This species is only known to breed in decaying vegetable matter, dead insects, or animal excreta, and there is reasonable doubt as to whether it is sometimes a true parasite, or purely a scavenger as we have assumed.

Spiders as Enemies of May-beetles

Although not generally active enemies, several species of spiders have been seen attacking live May-beetles at night. Most frequently the grubs are caught in the webs and are there taken by the spider, but the writer has seen one case of a truly predaceous attack. While collecting beetles from trees at Lafayette, Ind., May 20, 1912, an adult *Phyllophaga implicita* was seen to alight on a peach tree about dusk (7:45 p. m.), and several minutes later, after it had begun to feed, it was seized by a spider, determined by Dr. Nathan Banks as *Lycosa helluo* Wakeman.

Another spider, *Xysticus gulosus* Keys (Banks det.), with a captured *P. futilis*, was taken at Lafayette, Ind., May 12, 1915, by Mr. A. F. Satterthwait, of the Bureau of Entomology.

At Princeton, Ind., June 29, 1916, while collecting May-beetles from trees, a number of spiders, all of the same species and determined by Nathan Banks as *Plectana stellata* Hentz (Pl. XI, Fig. 46, 47), were observed attacking May-beetles (*P. implicita*) which had been caught in the webs, and the same spider was seen attacking May-beetles in a similar manner at Lafayette, Ind. Mr. G. G. Ainslie found an adult of *P. fusca* in the web of this spider at Knoxville, Tenn., and the writer saw an adult *P. congrua* attacked and killed by the same species at New Orleans, La.

Diseases of the larva

A Nematode Disease

A new white-grub disease, caused by nematodes, appeared in beneficial abundance in the vicinity of Lancaster, Wis., during the late summer and fall of 1915, but although many other localities where grubs were abundant were visited and a special search was made, the new

disease was not found elsewhere. August 19, 1915, the writer was informed by Mr. Frank S. Turner, a farmer living a mile east of Lancaster, that the grubs seemed to be dying in one of his fields where they had destroyed most of the corn that summer. An examination showed that a third or more of them were dead and yellow or decayed, and by October 5 at least 90 per cent. of the grubs had died. The disease was also prevalent in neighboring fields to a distance of three-fourths of a mile to a mile. With one exception, every field in which the dying grubs were found had been in timothy the year before, that is, the year the beetles were abundant, but whether this had any significance other than that such land is usually the worst infested with grubs, can not be told at this time. The one exception was a corn field which was in oats the previous year and adjoined a field which contained diseased grubs. According to Mr. Turner's observations the disease made its appearance in a very wet spell about the first of July, and five or six weeks later, when the writer visited the field, a third of the grubs had been killed. Towards the end of August and following a period of wet weather newly affected grubs again became numerous, but shortly after this a dry spell seemed to retard the spread of the disease. From these

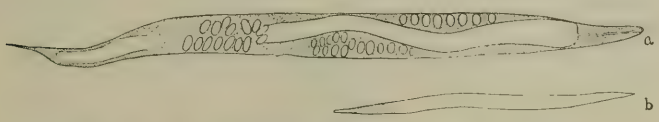

FIG. 44. Nematodes found infesting white-grubs: *a*, mature indivdiual; *b*, immature worm.

observations it seems likely that moisture plays an important rôle in the occurrence, abundance, and spread of this nematode infestation. Affected grubs were usually within six inches of the surface. They have a characteristic appearance (Pl. XII, Fig. 49), recently killed grubs being of a peculiar lemon-yellow color and the body fluids yellowish green. A few days or a week later they begin to take on a brownish color, due apparently to decay, and several weeks after the death of the grub decay and disintegration is complete. The bodies of the dead grubs are filled with thousands of small nematodes, and frequently, with the aid of a magnifier, the active parasites are plainly visible through the skin of the host. The appearance of the nematode as it occurs in the grub, is shown in Figure 44. Individuals which appeared mature measured 2.17 mm., the smaller ones measuring .39 to 1.00 mm., and the average being approximately .80 mm.

Grubs were sent to Dr. N. A. Cobb, who found two species present, one being *Diplogaster aerivora* Cobb, and the other immature Cephalobus (?) sp., the primary affection being considered by Dr. Cobb as due to the Diplogaster, although this point was not positively determined. An account of the life history and habits of *D. aerivora* has been pub-

lished by J. H. Merrill and A. L. Ford (51), who found it attacking *Leucotermes lucifugus* and grasshoppers' eggs in Kansas. The nematodes were found parasitic in the heads, and in no case were they found in the abdomen of *L. lucifugus*, although after the death of the host they might feed within or on any part of the body.

A Protozoan Disease

While investigating reported white-grub injury on the farm of Robert Evans, seven miles northwest of Hoopeston, Ill., September 25, 1912, Mr. W. P. Flint and the writer observed live and dead grubs lying on the surface, and upon close examination also found sickly or dead grubs just below the surface, their presence being indicated by a slight cracking of the surface crust (16). Specimens were sent to Dr. R. D. Glasgow, who was at that time employed by Dr. S. A. Forbes to investigate white-grub diseases, and he pronounced the affection due to a protozoan parasite. The field containing the diseased grubs was a 60-acre corn field, 15 acres of which had been ruined by grubs of the 1911 brood of May-beetles. The soil in the field was a rich black loam and the field had been in oats the preceding year. A month later (October 29) the field was again visited and dead grubs were found quite abundant in the soil in the worst-infested parts of the field. Most of those on the surface were dry and readily blown about by the wind. Many other diseased grubs, and some dead, were found in the soil at a depth of ⅛ to 1½ inches, their presence usually indicated by the cracking of the soil, as noted above. Grubs which were apparently free from the disease occurred 1 to 1½ feet below the surface, and although it was impossible to make an exact estimate it was evident that more than 50 per cent. of the grub population had been destroyed by the disease. It is interesting to note that although skunks had been active in searching for the grubs in this field, they had apparently not eaten any of the diseased grubs, neither those lying on the ground nor those just beneath the surface. The following season (September 30, 1913) the writer again visited the field and followed the plow in the infested area for a distance of 360 rods, but only 7 adult beetles and 11 grubs were found, and most of these were along the edge of the infested area where the disease was least prevalent in 1912. Patches in the field were dug to a depth of 1½ and 2 feet with similar results. The evidence showed rather plainly that the disease had destroyed most of the grubs.

A second outbreak of this protozoan disease was found October 6, 1915, on the farm of Mr. Ira E. Bryan, one mile north of Belvidere, Ill. Dead and sickly grubs were on and just beneath the surface as in the case at Hoopeston, above mentioned, and Mr. Bryan had noticed diseased grubs several weeks before our visit. An approximate estimate showed that at least 50, or possibly 75, per cent. of the grubs in this field were affected. It had been in sod the previous year and the grubs were from the 1914 brood of beetles. Neighboring fields heavily infested with grubs showed the same disease to be prevalent.

These are the only localities where the disease has been found, and in both cases it has proved a very effective check. Our facilities have not provided for a study of Protozoa, and nothing is known of the propagation of this species, either artificially or under natural conditions, whether it is a direct or indirect parasite, or whether it can be utilized artificially for the control of white-grubs.

The affected grubs are characterized by their habit of coming to the surface of the ground, or near to it, and at a season when, according to our observations, the natural migration would be downward, but they present no unusual appearance except that they look sickly and emaciated and gradually dry up—as one might expect any grub to do if exposed to the sun and wind on the surface of the ground where it could not re-enter. (Pl. XII, Fig. 48.)

Bacterial Diseases

To our knowledge, but one bacterial disease affecting white-grubs has been recorded as occurring in this country, although at least two are known to attack related species in Europe. Our American disease, due to *Micrococcus nigrofaciens* Northrup, has been studied and described by Miss Zae Northrup (52). She concludes that the organism causing

Fig. 45. A common white-grub (Phyllophaga sp.) showing typical infections of the bacterial disease due to *Micrococcus nigrofaciens*. Note the one leg with only blackened stump remaining; another, in an earlier stage, with only its end blackened; also the third infection at one of the spiracles.

the disease is present in soils in widely separated localities in the United States and probably through most of the states. The diseased grubs are characterized by a blackening of the affected parts (Fig. 45), and an excessive wetness of the soil favors the progress of the disease. It has been encountered wherever we have collected grubs, and Miss Northrup is undoubtedly right in concluding that it is generally distributed throughout the United States. According to our observations, grubs become infected only through wounds, and the infection is usually limited unless certain favorable conditions are present. Grubs are, in fact, often reared to maturity which have shown the infection in one or more of their legs. We can only conclude from this and other observations, together with

our knowledge of the constant occurrence of the Micrococcus in soils everywhere, that it is of minor importance in the control of Phyllophaga, except possibly under exceptionably favorable conditions, and that it can not be used for this purpose artificially. This disease has been studied in Porto Rico by Mr. R. H. Van Zwaluwenburg, and his conclusions (79), which agree with our own, are as follows: "The organism is present in our soils but its efficiency can not be increased by any practical means, for infection takes place usually only through a bruise or cut in the integument of the larva."

Fungous Diseases

Of the several species of fungus parasites of white-grubs, the so-called green muscardine fungus (*Metarrhizium anisopliae* Metsch. and its variety *americana* Pettit)* is the commonest and most wide-spread (Pl. XIII, Fig. 51—57). *M. anisopliae* was discovered by Metschnikoff, in 1878, attacking larvae of *Anisoplia austriaca,* a white grub of considerable importance in Europe. It has since been frequently referred to in literature and is now known to attack nearly all forms of insect life, being apparently cosmopolitan in its distribution. The first indication of the disease is a rigidity of the body, and this is followed shortly by the appearance of white mycelial threads, first at the joints, and later completely covering the body with a white velvety coat. Within a day or two the characteristic green spores develop—dark in the case of *anisopliae* and light green in the variety *americana.* This fungus has probably never been artificially employed with effective results on white-grubs although it has recently proven somewhat effective in Trinidad (64, 76) in the control of the sugar-cane froghopper (*Tomaspis varia* Fabr.). In 1913 the writer applied this fungus in several fields badly infested with white-grubs in Wisconsin and Indiana, using corn-meal cultures, some of which were grown at the Lafayette Station, but most of them furnished by Dr. S. A. Forbes. No results whatever were obtained in any case, although the grubs were abundant and the weather conditions were favorable to fungus growth. The green muscardine has also been used for the control of white-grubs in Porto Rico, and the results obtained there, which agree with our own, may be summarized from the report of the pathologist, John A. Stevenson (68). "At the south coast laboratory at Ensenada the fungus is present to such an extent as to seriously interfere at times with the progress of studies on the life history of the various beetles attacking cane. On the other hand no such success has attended the field trials which have been conducted in the neighborhood of Yauca. * * * The fact that it [the green muscardine fungus] does exist here and has not become epidemic would seem to militate against the success of present experiments, especially in the light of results obtained to date." While following the plow we have found isolated cases of Metarrhizium infection in grubs of the

* Variations in color and size of spores are thought by John R. Johnston (40) to depend upon the host or the media, not being of varietal rank, but merely indications of different physiological races.

genus Phyllophaga in various parts of Wisconsin, Illinois, Indiana, and Michigan, but have found it nowhere common. Scarabaeid grubs, and more especially grubs of the genus Ligyrus, are quite susceptible to this fungus in our breeding cages, and indeed it has occasionally interfered with our life-history studies, but the unusually favorable conditions in the cages can not be duplicated in the field, and, judging from our experience, the green muscardine can not be employed artificially as a means of controlling white-grubs in the northern half of the United States.

The white muscardine, *Isaria densa* Link (=*Botrytis tenella*), has been experimented with against the white-grubs in Europe, and a few investigators have claimed success, but the opinions of European investigators are conflicting on the subject and the actual value of its artificial use as a measure against white-grubs is yet to be demonstrated. On the other hand there is little doubt that its wide-spread natural occurrence among grubs in the field would prove an effective check upon their injuries, as is clearly indicated by the following record. In December, 1911, Mr. W. P. Flint, of the office of the State Entomologist of Illinois, found Phyllophaga grubs killed by *I. densa* very common, and in some places abundant, on the surface of the soil in many parts of southern Illinois, including the counties of Randolph, Marion, Jackson, Perry, Bond, Madison, and Fayette. The grubs collected by Mr. Flint and kindly sent to us by Dr. S. A. Forbes, were thoroughly mummified, as shown in the accompanying photograph (Pl. XIV, Fig. 59). The fields where these diseased grubs were found were in corn, wheat, oats, and cow-peas. Although most of the sick grubs came to the surface of the ground before dying, it was noticed by Mr. Flint that the birds apparently did not pick them up.

A fungus similar to *I. densa* (*Isaria farinosa* Dicks; Pl. XIII, Fig. 50)has likewise been tried by European investigators with much the same results as those reported for *I. densa*. *I. farinosa* is supposed to be the "Isaria stage" of a species of Cordyceps, possibly *C. militaris* Linn.

Pettit (56) also records *Cordyceps melolonthae* ? (Tul.) Sacc., and *Isaria vexans* Pettit as attacking Phyllophaga grubs.

The peculiar and characteristic Cordyceps growths on white-grubs have been occasionally mentioned in literature and most of them referred to the species *C. melolonthae, C. militaris,* and *C. ravenelii.* The first reference to Cordyceps on grubs in this country seems to have been made by Jacob Cist in 1824 (12). In our studies we have obtained but one true Cordyceps attacking Phyllophaga grubs, and this specimen, found in the forest tract at Trout Lake, Vilas Co., Wis., has been kindly identified for us by Dr. E. B. Mains as probably *C. ravenelii* Berk. and Curt., but it could not be determined with certainty without the fertile tip, which was broken off. We have also obtained from Mr. D. E. Walker, through the kindness of Mr. Harry F. Dietz, grubs attacked by *Cordyceps herculea* (Schw.) Sacc. (=*melolonthae*) (Mains det.). These

diseased grubs, which are undoubtedly *Xyloryctes satyrus*, were collected in a forest area at Little York, Ind., July 2, 1915.

The Isaria fungi are in most cases supposed to be one stage of the Cordyceps fungi, but our knowledge of the subject is meager and views are conflicting.

Our own studies with *Isaria farinosa* and *I. densa* indicate rather conclusively their ineffectiveness against the white-grub in the field under normal conditions. Indeed they are even less prolific and virulent than is the green muscardine fungus, and the conditions found necessary for their active growth are seldom if ever duplicated in cultivated fields, the perfect Cordyceps stage having been found by us only in forests or partly cut-over forest-land where the proper moisture and light conditions are to be found.

Pitcher-plants and Phyllophaga

Although probably of little economic importance, mention may be made of an interesting observation made in southwestern Georgia in a swamp near Coolidge by Dr. W. Dwight Pierce (57) on the insect-catching habits of pitcher-plants. In practically every pitcher of *Sarracenia catesbaei* Ell., a common species in southwestern Georgia, Phyllophaga remains were found.

Miscellaneous predaceous enemies

Birds

Birds are among the most efficient, if not the most active, natural agencies in the control of white-grubs throughout the United States, more especially in the newer regions where they are still to be found in large numbers. Of the 52 different kinds of birds presently to be mentioned as benefiting the farmer by destroying May-beetles and their progeny, probably the crow (*Corvus brachyrhynchos*) and the crow blackbird (*Quiscalus quiscula*) are the most valuable. They are the constant companions of the plowman and diligently pick up the grubs and beetles as they are exposed. According to the records of the Biological Survey (4) both May-beetles and grubs have been found in the stomachs of crows every month of the year except January. An instance of the capacity of blackbirds for grubs was given the writer by Mr. Henry Holzinger, of Lancaster, Wis. While a timothy sod was being plowed in 1912 a single blackbird was seen by him to eat as many grubs as possible and then, with its mouth full of them, to fly away. By actual count this bird destroyed twenty grubs in from one to two minutes. This habit of the blackbird of eating a large quantity of grubs and then flying away with the bill full, is a common one according to our observations.

In addition to the crow and the crow blackbird the Bureau of Biological Survey has listed the following birds as feeding on May-beetles or white-grubs. They are here given in the order of their probable

value as enemies of Phyllophaga: robin (*Planesticus migratorius*),* Franklin's gull (*Larus franklini*)*, red-winged blackbird (*Agelaius phoeniceus*)*, killdeer (*Oxyechus vociferus*)*, horned lark (*Otocoris alpestris*)*, ruffed grouse (*Bonosa umbellus*)*, upland plover (*Bartramia longicauda*)*, meadow-lark (*Sturnella magna** and probably *S. neglecta*), brown thrasher (*Toxostoma rufum*), phoebe (*Sayornis phoebe*), cuckoo (*Coccyzus erythrophthalmus*), screech owl (*Otus asio*), barred owl (*Strix varia*)*, great horned owl (*Bubo virginianus*), Eastern bluebird (*Sialia sialis*), house wren (*Troglodytes aedon*)*, prairie chicken (*Tympanuchus americanus*), quail, or bob-white (*Colinus virginianus*), sparrow hawk (*Falco sparverius*)*, broad-winged hawk (*Buteo platypterus*)*, red-shouldered hawk (*Buteo lineatus*), red-tailed hawk (*Buteo borealis*), scissor-tailed fly-catcher (*Muscivora forficata*), crested flycatcher (*Myiarchus crinitus*), and the English sparrow (*Passer domesticus*)*. (4, 5, 6, 7, 8, 9, 19, 20, 21, 35, 41, 42, 50, 61, 66.)

Mr. Norman Criddle (14) mentions the robin, flicker, grackle or crow blackbird, cowbird, and gull as enemies of grubs, but the crow is said to rank highest according to observations made in Manitoba, Canada. The cowbird (*Molothrus ater*), although having a bad reputation, is said to be an excellent destroyer of white-grubs, usually eating the smaller ones, but when these are not available killing the larger ones by biting their heads and eating only parts of the grubs. Mr. A. C. Burrill mentions (11) the herring gull (*Larus argentatus*) as feeding on May-beetles, but its actual usefulness in this connection is not known.

The European starling (*Sturnus vulgaris*), which was introduced into this country within comparatively recent years, was reported to us in 1915 as an active destroyer of Cyclocephala grubs occurring in lawns at Staten Island, N. Y., and according to Mr. E. H. Forbush (27) it likewise feeds on May-beetles and white-grubs. Whether its appearance in this country will eventually prove a menace to fruit crops or to the more beneficial native birds, can not as yet be foreseen.

In his study of the food habits of the English sparrow (*Passer domesticus*), Dr. C. V. Riley (61) found that 7 out of 92 stomachs examined contained grubs or May-beetles, while 40 contained the remains of either Tiphia or *Myzine sex-cincta* (=*Elis 5-cincta*), both of which are now known to be very important white-grub parasites. This particular study certainly shows this sparrow as noxious in its relation to the white-grub, but it has been seen to follow the plow more or less and to destroy grubs. At Elk Point, S. Dak., Mr. C. N. Ainslie, of the Bureau of Entomology, saw both English and field sparrows feeding on grubs exposed by a corn lister. At Lancaster, Wis., an observing farmer, Mr. Holzinger, told us of the inestimable value of birds in destroying grubs, mentioning especially the blackbirds and English sparrows. When plowing a sod field in 1912 he saw a sparrow following the plow. It pecked at five grubs without eating one and then ate the sixth, and upon

* Those starred eat both beetles and grubs; others, only beetles

examination it was found that it had killed the first five, the head having been completely pulled off in one case. While following a plow in a badly infested field May 11, 1916, at Rockton, Ill., the writer saw many grubs with crushed heads, and three or four sparrows were noticed to be actively engaged pecking at the grubs as soon as they were turned out by the plow, seldom eating one but seeming to delight in pecking into their heads. At Lafayette, Ind., May 14, 1891, Prof. F. M. Webster saw an English sparrow feeding on Phyllophaga beetles which had fallen to the ground beneath an electric light the night before, and this observation has been made by others also.

A gull, supposedly Franklin's gull (*Larus franklini*), has been reported from various places in Nebraska, Iowa, and South Dakota as very fond of grubs. Mr. C. N. Ainslie saw flocks of gulls following the plow in infested fields at Elk Point, S. Dak., in May, 1913. They appeared to feed exclusively when on the wing, swooping close to the ground and capturing the grub without alighting. In 1912 white-grubs were very destructive near Tabor, S. Dak., and the owner of a badly infested farm told the writer of the great value of the gulls and blackbirds in destroying the grubs behind a plow or cultivator. His observations on the habits of the gulls agreed with those of Mr. Ainslie, and the blackbirds in flying to the furrows and back to a near-by grove formed a black unbroken ellipse.

In a letter to the Bureau of Entomology dated June 18, 1910, Mr. C. H. Loomis, of Platteville, Wis., refers to pigeons, as well as to crows and blackbirds, as actively feeding on grubs turned up by the plow.

Other birds which have been reported to feed on white-grubs or May-beetles are the red-bellied woodpecker (*Centurus carolinus*) and the red-headed woodpecker (*Melanerpes erythrocephalus*), according to the observations of Townend Glover (32); the blue jay (*Cyanocitta cristata*), "golden woodpecker" (*Colaptes auratus?*), according to Hargitt (38); chuck-wills widow (*Antrostomus carolinensis*), according to Dr. C. V. Riley (62); the catbird (*Dumatella carolinensis*), wood thrush (*Hylocichla mustelina*), and hermit thrush (*H. guttata*), according to Dr. S. A. Forbes (23, 25); and several grackles (*Quiscalus macrourus, Q. quiscula aeneus, Q. quiscula aglaeus, Q. major,* the common ani (*Crotophaga ani*),and the grooved-bill ani (*C sulcirostris*), the laughing gull (*Larus atricilla,*) the Virginia rail (*Rallus virginianus,*) meadow-lark (*Sturnella magna argutula*), sora (*Porzana carolina*), and the rice bird (*Dolichonyx oryzivorus*), according to observations made in Louisiana by Prof. G. E. Beyer (77). *Crotophaga ani* and *Holoquiscalus brachypterus*) feed on white-grubs in Porto Rico, according to Van Dine (77).

While many of the above-mentioned birds are active grub-destroyers in the field, probably no one of them compares with the robin in its ability to detect and unearth grubs in lawns, a fact which makes them doubly valuable since grubs are much more difficult to control in grass lands than in cultivated fields. Evidently robins detect the grub by their keen sense of hearing, and having once ascertained its location they

vigorously dig into the sod until it is unearthed. Mr. E. H. Forbush (28) reported an unusual abundance of white-grubs in a cranberry bog at Wareham, Mass., nearly every plant being killed; but the following season robins appeared in large numbers, and by digging into the soil and pulling out the grubs they practically cleared the field of the pests. The crow is often similarly active in destroying white-grubs in sod land, especially when they are abundant. In 1912 the writer saw a badly infested pasture at Galena, Ill., in which the sod had been literally overturned by the crows in their search for grubs.

Wild Mammals and Amphibians

Of the mammals known to destroy white-grubs and the parent May-beetles the common skunk (*Mephitis mephitis*—Pl. XV, Fig. 60) is undoubtedly the most important, and it has been repeatedly mentioned, since the early records by Harris, as a very efficient destroyer of white-grubs. In speaking of the remarkable capacity and fondness of skunks for grubs Dr. Lintner remarks (45): "I have often watched them, and, incredible as it may seem, I could not say that they ate less than half a bushel daily." Mr. D. E. Lantz, in his discussion (44) of the "Economic Value of North American Skunks", speaks of the common skunk (*Mephitis mephitis*), the white-backed skunk (Conepatus sp.), and the little spotted skunk (*Spilogale interrupta*) as very important destroyers of white-grubs and May-beetles, basing his conclusions on extensive field observations as well as on studies of stomach contents; and other workers of the U. S. Biological Survey (21) write similarly. Mr. Frank C. Pellett (54) concludes from five years' observation of this mammal in the field and in confinement that it is a valuable friend in destroying insect and rodent pests, and that "the poultry-killing habit is accidental and unusual and confined to a small percentage of the individuals". Because of its nocturnal habits the skunk is seldom seen at work, but Mr. Norman Criddle (14) tells of watching a skunk catching May-beetles at night, and later in the season, after the beetles had disappeared, of observing the activities of skunks in search of grubs. In an 8-acre field infested with white-grubs, near Aweme, Manitoba, the work of two or more skunks was quite apparent, and he estimated that they had destroyed 116,160 grubs in this one field.

In connection with our own studies we have frequently observed the work of the skunk. In 1912 Mr. Henry Geske, of McGregor, Iowa, told us of observing an old skunk roll up grub-infested sod, thus exposing the grubs, which she and her young ate eagerly. More often the animal detects the presence of a grub by a keen sense of smell and secures it by digging a small hole at the spot where she knows it to be. The writer was called to Lagro, Ind., November 3, 1911, to investigate a reported white-grub injury to fall wheat. A week previous the grubs were common near the wheat plants, cutting off the roots, but on the day when we visited the field scarcely a grub could be found, most of them having been destroyed by skunks; at nearly every stalk of wheat

showing grub injury the typical skunk excavation was to be found but no trace of living grubs. A similar observation was made in an infested wheat field October 9, 1914, near Battle Creek, Mich. The farmers in the infested districts of Illinois, Michigan, Wisconsin, and Iowa are realizing the economic importance of the skunk, and are in many cases prohibiting hunters from killing it, and in other ways giving it their protection.

The common mole (*Scalopus aquaticus*) is probably next in importance. Mr. Theo. H. Scheffer (65), after examining the stomach contents of 200 moles taken in all months of the year, concludes that white-grubs and earthworms constitute the bulk of their food; and Mr. J. A. West (82) finds from a study of the stomach contents of moles collected under varying conditions in various parts of Illinois, that a good per cent. of the food of moles consists of white-grubs and May-beetles.

Mr. George G. Ainslie, of the Bureau of Entomology, made some interesting observations on the feeding habits of the common mole in confinement. The mole, which was taken in a field at Nashville, Tenn., June 28, 1911, was fed ten large Phyllophaga grubs, two wireworms, and one web-worm in succession, all of which it ate with relish. The mole would eagerly take a grub, quickly crush its head between its teeth, and leisurely eat the remainder of the grub.

At Farmington, Mich., October 23, 1914, A. F. Satterthwait saw an abundance of mole tunnels in an old timothy sod badly infested with grubs, the unusual amount of mole work in this field indicating that they, as well as skunks, were attracted there to feed on the grubs. A similar observation was made by Joe S. Wade, of the Bureau of Entomology, at Shawnee, Okla., the mole tunnels being conspicuous, especially in the worst-infested parts of the field. At Ashboro, Indiana, we found a quantity of May-beetle remains at the end of a mole tunnel, and on several occasions have traced the mole-runs in corn fields infested with grubs and found them leading directly to hills where grub injury had occurred. All our field observations indicate that the moles play a significant rôle in the natural control of white-grubs.

Other animals which have been seen to feed on white-grubs or May-beetles are the raccoon (*Procyon lotor*), the coyote (*Canis latrans*), the fox, the opossum (*Didelphys virginiana*), and the gopher. (21, 45, 55.) The first three are comparatively rare in most regions where white-grubs are important pests, and the ultimate value of the gopher is questionable because of its injury to farm crops. Mr. J. S. Wade received a letter from a farmer of Shawnee, Okla., dated July 3, 1913, who reports killing a small striped gopher, or ground-squirrel—supposedly *Citellus tridecemlineatus*—in the immediate vicinity of grub-infested hay land and of examining its stomach, which contained about a dozen partly disintegrated grubs. Franklin's spermophile (*Citellus franklini*) feeds on white-grubs, according to an examination of the stomach con-

tents made by Mr. Vernon Bailey (3); and such animals as the weasel, martin, wolf, and hedgehog are said to feed on white-grubs (17, 59).

The shrew is also well known for its fondness for May-beetles and white-grubs, and A. F. Shull (67) estimates that a single short-tailed shrew (*Blarina brevicauda*) during one month might kill and use for food 450 May-beetles; and Mr. F. E. Wood (83) writes: "Probably no other mammal [referring to the above species], unless it be the skunk when on its good behavior, is so uniformly beneficial to the farmer."

The badger (*Taxidea taxus*) is very fond of white-grubs, and in some regions its beneficial activities have been noticeable. At Deford, Mich., July 25, 1913, Mr. A. F. Satterthwait, of the Bureau of Entomology, saw a white-grub-infested June-grass sod of about three acres dug up in a way that suggested the work of swine in rooting for grubs, and, on inquiry, Mr. Earl Lockwood, the owner, stated that badgers which lived in the adjacent woods were responsible for this work.

The common toad (*Bufo americanus*) is very fond of May-beetles and has been seen at night beneath electric lights, feeding on the beetles as they drop, and during the evening in pastures, capturing May-beetles as they issue from the soil. At Wellington, Kan., May 23, 1911, E. G. Kelly saw toads eating beetles beneath lights and as they emerged from the grass in the evening, and in one case he noticed that a single toad ate more than nineteen beetles in succession. Mr. A. H. Kirkland (43) concludes from an examination of the stomach contents of many specimens that May-beetles constitute about 6 per cent. of the food of the common toad, and similar conclusions have been reached by other observers.

Frogs are also known to feed on May-beetles. In one frog's stomach examined by Mr. C. W. Hargitt six May-beetles were found (33); in another, that of a medium-sized frog, as many as ten beetles were found, according to G. H. Perkins (55); and P. R. Hoy (39) speaks of having found 8 May-beetles in a large spotted frog.

The slimy salamander (*Plethodon glutinosus*) may eat May-beetles, according to observations by Prof. H. A. Surface (71), who found the remains of a Phyllophaga adult among the stomach contents of this animal.

Field mice also evidently feed to some extent on May-beetles. At Deford, Mich., June 25, 1914, A. F. Satterthwait found quantities of May-beetle fragments under trash in mice runways at the base of a partially defoliated Carolina poplar; and G. H. Perkins (55) reports mice (probably referring to field mice) as feeding on Phyllophaga.

Domestic Animals

None of the enemies of Phyllophaga that have been mentioned rank as high in this rôle as do some of our domestic animals, and of these pigs are by far the most important. Their fondness for May-beetles and white-grubs, more especially for the latter, has been commonly observed, and their use for controlling white-grubs has been recommend-

ed for years. (Pl. XIV, Fig. 58.) If pastured in infested ground, pigs will literally plow up the land in their search for grubs, and in a short time will practically eradicate the pests. Dr. Forbes (26) made an experiment to determine accurately the value of the pig in destroying grubs. One hundred pigs and 8 sows were turned into an enclosed 10-acre field September 23, and within 20 days 86 per cent. of the grubs were destroyed, and in 27 days less than 1 per cent. of the original infestation remained—a benefit of over 99 per cent. If we estimate 34.6 grubs per hill—the count made at the beginning of the experiment—and 3556 hills to the acre (hills 3⅓ feet apart each way) it will be seen that the pigs destroyed something like 1,218,067 grubs in 27 days, that is, 11,278 grubs per animal. It was further noted that the pigs apparently suffered no ill effects from the continuous grub-ration.

An interesting and illustrative account of the probable important rôle played by swine in the control of white-grubs in Texas twenty or more years ago was given us by Mr. N. Mowinkle, a resident of Texas for over sixty years, and of Travis county, where the grubs have recently caused immense losses, for most of this time. Until comparatively recent years it was the custom of the Indians to burn over the mesquite meadows every fall, and hogs were always given free range. Previous to the year 1877 no fencing of any kind was used, but about that time barbed wire came into use. Burning over the land was discontinued fifteen or twenty years ago and laws requiring that hogs should be fenced were enacted. About ten, or possibly twelve, years ago the white-grubs began to destroy the pastures; in other words, they first appeared in injurious numbers five to seven years after the burning over of the land was discontinued and fencing for hogs was required. No doubt these two changes in the situation were in a large measure responsible for the increase of the white-grubs in certain parts of Texas.

That the eating of white-grubs under certain conditions may be harmful to pigs, occasioning infestation with intestinal parasites, has been shown by Dr. C. W. Stiles (69), who says that the giant thorn-headed worm (*Gigantorhynchus hirudinaceus* = *Echinorhynchus gigas*), an injurious intestinal parasite of swine (Fig. 46), passes one stage of its life in the bodies of white-grubs of the genus Phyllophaga,* the pigs obtaining them by eating infested grubs, which themselves become infested by way of the excrement of parasitized pigs. Especial care should be taken to pasture brood sows in fields on which pigs have not been pastured for two or more years.

Turkeys are extremely fond of grubs and we have seen the sod of pastures overturned by these birds in their search for the pests.

Chickens are not so active as turkeys in their search for grubs in unplowed ground, but it is wise to encourage them to follow the plow and cultivator whenever possible, and they will eagerly pick up every grub or May-beetle exposed. In one case which has come to our at-

* Other authors have shown a similar relation to exist between this worm and two common European grubs (*Melolontha vulgaris* and *Cetonia aurata*).

tention a heavily infested 15-acre field was cleaned of grubs by giving poultry the run of the field during cultivation. Another instance of the value of chickens in this connection was called to our attention by Mr. Frank Acker, of Middleton, Wis., whose potato crop was practically destroyed by grubs in 1912 excepting the part near the farm buildings, where the chickens had the run of the field. When sod is loose because its roots are cut off by grubs, chickens will scratch it away in their search for the insects much as do turkeys. When the beetles are abundant, on nearly every farm the chickens may be seen searching for May-beetles beneath the trees.

Portable poultry houses, which can be transferred to any particular field or part of a field as it is being plowed or cultivated, were used in

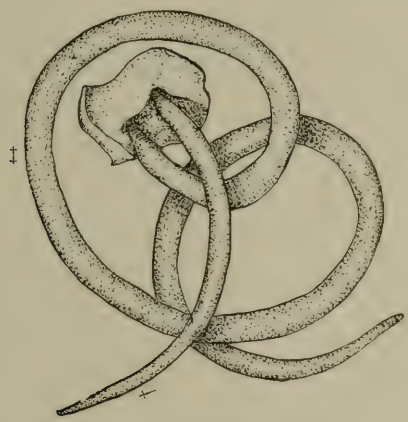

FIG. 46. Thorn-headed worms *(Gigantorhynchus hirundinaceus)* attached to piece of pig's intestine; †, male; ‡, female. Enlarged. (Redrawn from Ransom, Yearbook U. S. Dept. Agr., 1905.)

Europe over fifty years ago. Such houses, according to M. Maurice Girard (30), should have a capacity for 100 to 200 chickens, and should contain perches, numerous egg-laying compartments, and a receptacle to catch the manure. The chickens forage about the house during the day, returning at night, and a continuous ration of grubs has no perceptible effect on the taste of the eggs as does a continuous ration of certain lepidopterous larvae.

Rarely dogs have been trained to follow the plow and pick up beetles and grubs (17). At Washington, Ind., April 16, 1915, Mr. D. G. Tower,

of the Bureau of Entomology, observed a black and tan terrier following a plow and eating the grubs as they were exposed. The dog seemed to find the grubs by scent as well as by sight, for frequently it would dig for those which were completely covered. Most of those eaten, according to Mr. Tower's observation, were Cotinus (Allorhina), but undoubtedly the dog would have eaten Phyllophaga grubs with relish had they been as abundant.

It is well known that many cats are fond of May-beetles. Prof. H. A. Surface (70) reports that a cat in his possession would catch May-beetles as they came out of the ground in the evening, and that it once ate so many that it was made sick and vomited nearly a pint of May-beetle remains.

Errata

Page 97, line 17, for first *larval* in the line, read *pupal.*

Page 112, in legend, for *jonessi* read *jonesii.*

Page 114, in legend, for *or* read *of.*

Page 131, in legend, for *hirundinaceus* read *hirudinaceus.*

Page 138, last line, for *coccoon* read *cocoon.*

Plate XII, explanation page, next to last line, for *acrivora* read *aerivora.*

Plate XIII, explanation page, next to last line, for *White-grubs* read *White-grub.*

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PLATE III

Fig. 1, 2. Mature Tiphia larvae eating the last remains of a white-grub. Natural size.

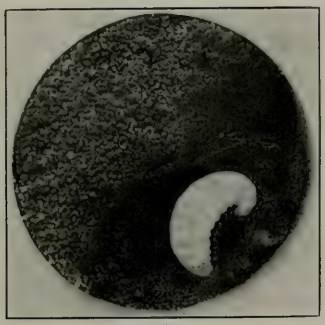
Fig. 3. Same larva, a few hours later, beginning foundation of cocoon. Natural size.

Fig. 4. Completed cocoon in a tin-box cage.

Fig. 5, 6. *Tiphia punctata* larvae in their characteristic position on grub; front and rear views. Natural size.

Fig. 7. Tiphia cocoon from which a parasite (*Anthrax parvicornis*) has issued, characterized by the squarely cut-off tip of coccoon.

PLATE III



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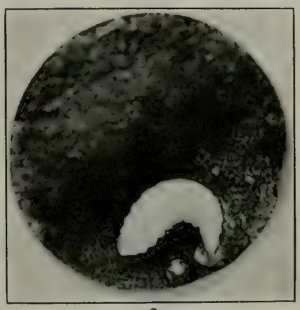

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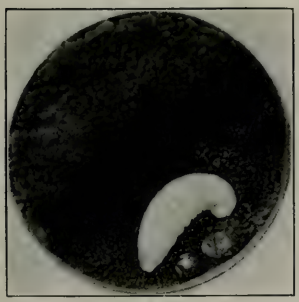

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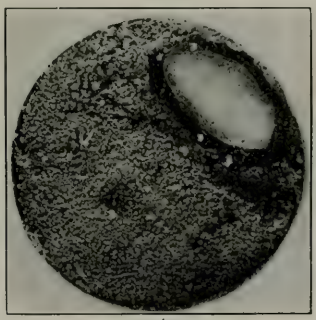

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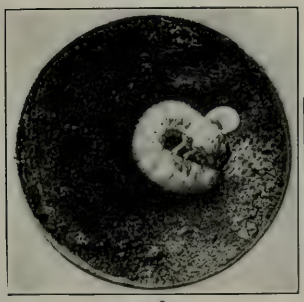

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PLATE IV

Fig. 8, 9. Tiphia cocoons, enlarged and natural size.
Fig. 10, 11. Elis cocoons, enlarged and natural size.
Fig. 12. *Chrysanthrax fulvohirta* Wied., a parasite of Elis. Enlarged.

PLATE IV

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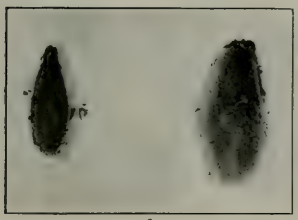

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PLATE V

Fig. 13. *Elis 5-cincta* egg on under side of paralyzed white-grub, July 25, 1914. Natural size.

Fig. 14–16. Same grub as shown in Fig. 13, the Elis larva in Fig. 14 not over two days old, that in 15 not over four days, and that in 16 about five days. Natural size.

Fig. 17. Oblique view of Elis larva feeding on white-grub.

PLATE V

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PLATE VI

Fig. 18. Phyllophaga grub parasitized by *Microphthalma disjuncta;* the anal end of larva with the two posterior spiracles showing through body wall. Natural size.

Fig. 19. Same grub, a day later, with Microphthalma puparium. Nothing remains of the grub but its dried and shriveled skin. Natural size.

Fig. 20. Grub parasitized by *Microphthalma disjuncta*, beginning to liquefy. Natural size.

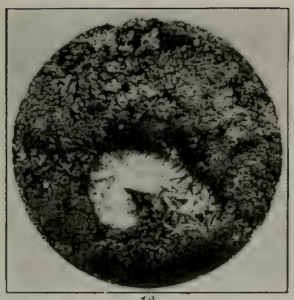
Fig. 21. A grub (*Aphonus pyriformis*) parasitized by several *Ptilodexia harpasa* maggots. No liquefaction of grub as in Fig. 20. Natural size.

Fig. 22. *Microphthalma disjuncta*, male, side view. Enlarged.

Fig. 23. The same, dorsal view. Enlarged.

Fig. 24. *Microphthalma disjuncta* puparium in dried grub-skin as collected in the field. Natural size.

PLATE VI



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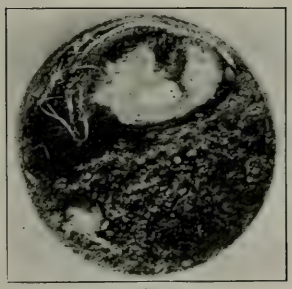

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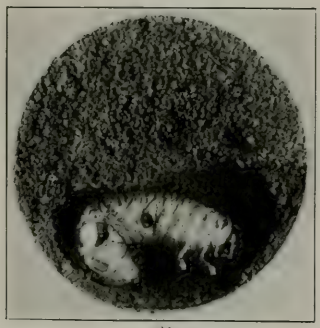

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PLATE VII

Fig. 25. *Ptilodexia harpasa* Walk., a parasite of white-grubs. Enlarged.
Fig. 26. *Promachus vertebratus* Say. About natural size.
Fig. 27. *Promachus fitchii* O. S., female. About natural size.
Fig. 28. *Harpalus pennsylvanicus* Dej. Slightly enlarged.
Fig. 29. *Pelecinus polyturator* Dru., female. Natural size.
Fig. 30. *Ophion bifoveolatum* Brullé, female. About twice natural size.

PLATE VII

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PLATE VIII

Fig. 31. *Deromyia winthemi* Wied., male. About twice natural size.

Fig. 32. *Tabanus atratus* Fabr., male and empty pupal exuvia. Both enlarged to same magnification.

PLATE VIII

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PLATE IX

Fig. 33. *Tabanus atratus* Fabr., male. Natural size.

Fig. 34. *Tabanus sulcifrons* Macq., female. Natural size.

Fig. 35. *Tabanus sulcifrons* Macq., femals. Enlarged.

Fig. 36. The same, empty pupal exuvia. Enlarged to same magnification as Fig. 35.

Fig. 37. *Tabanus atratus* Fabr., egg mass and individual egg parasitized by *Phanurus tabanivorus*. (After Hart.)

Fig. 38. *Deromyia umbrina* Loew, eggs. About twice natural size.

PLATE IX

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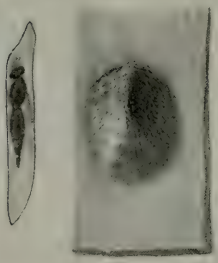

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PLATE X

Fig. 39. *Phanurus tabanivorus*, female, an egg parasite of *Tabanus atratus*. (After Hart.)

Fig. 40. Phyllophaga adult bearing two eggs of *Cryptomeigenia theutis* on side of abdomen. Slightly enlarged.

Fig. 41. *Pyrgota undata* Wied. (left) and *P. valida* Harr. (right) puparia. Much enlarged.

PLATE X

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PLATE XI

Fig. 42. *Pyrgota valida* Harr., female. Enlarged.
Fig. 43, 44. Grubs showing Mermis parasites within body. Natural size.
Fig. 45. Mermis, or hairworms, obtained from white-grubs. Natural size
Fig. 46, 47. *Plectana stellata* Hentz, male and female. (After McCook.)

Plate XI

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PLATE XII

Fig. 48. Emaciated grubs affected by a protozoan disease. Natural size.

Fig. 49. White-grubs killed by nematodes (? *Diplogaster acrivora*). About natural size.

Plate XII

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PLATE XIII

Fig. 50. Phyllophaga adults attacked by a fungous disease (due to *Isaria farinosa*). Natural size.

Fig. 51, 52. Early stages of *Metarrhizium anisopliae* infection, the white mycelial threads appearing at joints of body.

Fig. 53. A later stage of Metarrhizium, the green spores beginning to appear. Natural size.

Fig. 54. Matured green Metarrhizium spores covering body of beetle.

Fig. 55. The same covering body of a *Cotalpa lanigera* grub. Note characteristic beads of liquid accumulating just back of the head. Natural size.

Fig. 56, 57. White-grubs and Promachus larva covered with white mycelial threads of Metarrhizium. Natural size.

Plate XIII

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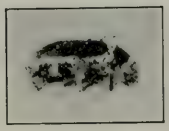

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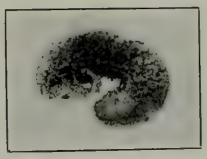

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PLATE XIV

Fig. 58. White-grub-infested corn-field uprooted by hogs in their search for the larvae.

Fig. 59. Mummified white-grubs which have been attacked by a fungus (*Isaria densa*). Natural size.

PLATE XIV

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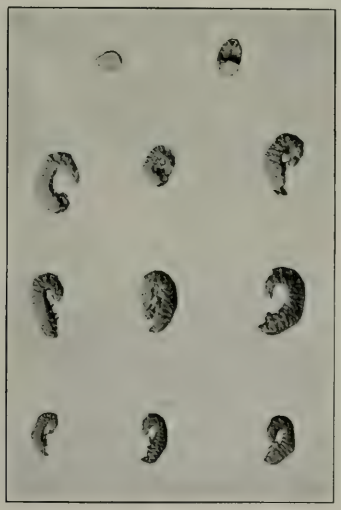

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PLATE XV

Fig. 60. The common skunk, *Mephitis mephitis.*

Fig. 61. Parasite of carabid larva, the parasite pupa attached to its host in characteristic position. Twice natural size.

Plate XV

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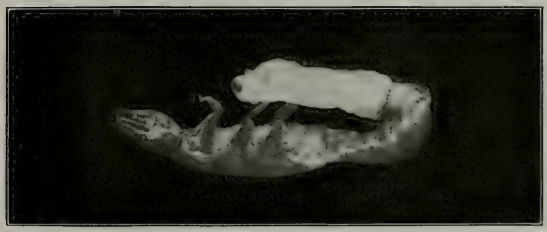

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ARTICLE VI.—*Some Recent Changes in Illinois River Biology.** BY STEPHEN A. FORBES AND ROBERT EARLE RICHARDSON.

The principal causes of change in the biological environment of the Illinois River which have come in since 1899 are the opening of the drainage canal of the Sanitary District of Chicago in January, 1900, a great increase in the amount of Chicago sewage emptied into the stream, and an extensive reclamation of the river bottoms for agricultural uses; and it is our present purpose to trace the principal effects of these changes upon the life of the stream. Although this study has had primarily a purely scientific motive, it has bearings of a practical character which we have followed out in some cases beyond the boundaries of our proper inquiry, with a view to making our results available, or at least suggestive, to those who have to deal with problems of sewage disposal, fisheries, bottom-land agriculture, and the like.

The principal changes due to the three causes above mentioned are presented summarily in the following numbered sections:—

1. The opening of the drainage canal of the Sanitary District of Chicago, January 17, 1900, admitted a flow of sewage-laden lake water which greatly increased the average depth and flow of the Illinois and lengthened the period and extended the range of its overflows. During the ten years preceding 1900 the average flow of the river at Peoria, 110 miles down-stream, was 8,391 cubic feet per second (or "second feet") †; but the flow of the sanitary canal alone in 1913 averaged 7,193 sec. ft., or 85.7 per cent. of the Peoria flow of the original river.‡

If we take account of some 600 sec. ft. of Lake Michigan water coming into the Illinois River by way of the old Illinois and Michigan Canal, which is, of course, additional to the contribution of the sanitary canal, we have left 7,791 sec. ft. as the average flow from the natural watershed of the stream above Peoria during the decade just preceding 1900. Combining the increments from the two canals, we find just half the average Peoria flow derived in 1913 from Lake Michigan.

At *average low water* of the above-mentioned decade just preceding 1900, the flow at Peoria was only 17 per cent. that of the canal in 1913, and at the *lowest* rate of discharge (723 sec. ft.) it was only 10.5 per cent. At the *highest* water of the period on the other hand, the canal, if open at the time, would have increased the flow of the stream by less than 10 per cent. The ratio of canal to river water at the lowest river level was over eight times that at the highest. The effect of the canal upon the rising river is therefore to hasten the onset of the overflow and to increase the area greatly in the beginning, but this effect diminishes as

* The present brief paper is an abstract only of some of the more general and significant parts of the product of a long series of studies of the biology of the Illinois River and its dependent waters which will be reported in detail in a number of articles now in course of preparation.

† Jacob A. Harman, in the Report of the Illinois State Board of Health on Sanitary Investigations of the Illinois River Tributaries, in 1901.

‡ Alvord and Burdick, Report on the Illinois River and its Bottom-lands (1915), p. 37.

the river continues to rise and it does not greatly expand the overflow when at its highest. It may thus materially increase the length of the overflow period without adding greatly to the area finally covered. All these effects of the canal affluent diminish, of course, down-stream, as the normal flow of the river is increased by the addition of tributary waters; and at the mouth of the river, in times of flood, less than 6 per cent. of the present flow of the stream comes from the sanitary canal. The biological importance of this extension of overflow conditions will be more clearly seen when we discuss the sources of supply of the river plankton.

We have shown, in an earlier paper, that the average depth of the Illinois River at Havana, 173 miles below the mouth of the sanitary canal, was about three feet greater during the 10-year period following upon the completion of the canal than during the 10-year period immediately preceding; and Alvord and Burdick, comparing the gage readings for fourteen years after and ten years before the opening of the canal, make this difference five feet for Peoria and three feet for Grafton, at the river's mouth.*

Not quite all this increase in depth can be fairly attributed to canal water, for the rainfall was somewhat less in the drainage basin of the Illinois during the earlier of these two periods than during the later. The average for the part of the state north of the mouth of the Illinois River was 34.09 inches per annum for the ten years from 1890 to 1899, and 35.92 inches for the period from 1900 to 1909. The rainfall for the 10-year period just preceding the opening of the canal was 1.83 inches per annum less than in the next ten years.†

If, however, we compare Havana levels from 1879 to 1899 inclusive, with those of the ten years next following, we find the average for the above twenty-one years to be 6.9 feet, and that of the ten years from 1900 to 1909 to be 9.7 feet—an increase at that point of 2.8 feet fairly attributable to the canal.

2. This greater volume of water throughout the year has also produced a greater expanse and depth of the bottom-land lakes, which commonly stand at about the level of the river itself. This fact is well illustrated by the change in Thompson Lake, near Havana—one of the largest lakes of the Illinois River series—as shown by two published tables of lake levels and corresponding differences of area, for the summer months (June to September) of thirty-four years, from 1874 to 1907 inclusive.‡ From the first of those tables we learn that the average level of the lake for twenty-six summers preceding 1900 was 429.46 feet above the sea, and that for the eight years next following this average was 433.06 feet §

* Alvord and Burdick's Report, p. 28.

† The data for this comparison were obtained from an article on the "Climate of Illinois," by Prof. J. G. Mosier, published as Bulletin No. 208 of the University of Illinois Agricultural Experiment Station.

‡ Report of the Submerged and Shore Lands Legislative Investigating Committee, Vol. I., p. 171.

§ These levels are equivalent to 5.09 ft. and 8.69 ft., respectively, on the Havana gage.

—a difference of 3.6 feet in the summer depth of the lake due to the opening of the sanitary canal; and we further find, by comparing these lake levels with the areas of the lake at different depths, as shown by the second of the tables, that the summer expanse of the lake averaged 1,943 acres before 1900, and 5,072 acres since 1899—an increase of more than two and a half times in the area of this lake, due to the higher levels produced by the canal.

AVERAGE LEVELS OF THOMPSON LAKE,
JUNE, JULY, AUGUST, AND SEPTEMBER,
1874–1907

Year	Thompson Lake Memphis datum * Elevations above	Havana gage
1874	433.25	1.48
1875	437.6	5.93
1876	439.25	7.58
1877	435.62	4.95
1878	438	7.33
1879	434.62	3.95
1880	437.37	6.70
1881	436.12	5.45
1882	440.75	9.08
1883	436.7	5.03
1884	436.7	5.03
1885	437.5	5.88
1886	435.87	4.20
1887	433.75	2.08
1888	437.87	6.20
1889	438	6.33
1890	437.75	6.08
1891	437	5.33
1892	441.5	9.83
1893	435.75	4.08
1894	435.25	3.58
1895	434	2.33
1896	436.62	4.95
1897	435.75	3.08
1898	437	5.33
1899	436.25	4.58
1900	438.12	6.45
1901	436.87	5.20
1902	444.87	13.20
1903	440.87	9.20
1904	439.75	8.08
1905	440.75	9.08
1906	438.25	6.58
1907	443.62	11.95
Average, 1874–99	436.76	5.09
Average, 1900–07	440.36	8.69

* "Memphis datum" is 7.3 feet below sea-level.

INCREASED ACREAGE OF THOMPSON LAKE CORRESPONDING TO INCREASING LEVELS

As levels increase from—	Area of lake increases, for each tenth of a foot, by—
4.41 to 5.13 feet	4.72 acres
5.13 to 6.08 "	8.68 "
6.08 to 7.08 "	15.48 "
7.08 to 8.08 "	4.56 "
8.08 to 9.08 "	3.79 "
9.08 to 10.08 "	2.56 "
10.08 to 11.08 "	1.96 "

3. A secondary effect has been to narrow permanently the belt of shallow weedy water along the banks of the stream in midsummer, and to do the same, at least temporarily, along parts of the shore of many of the lakes. The river waters now commonly reach in midsummer to the bases of the willows, permanently covering new banks of steeper slope than the original margins, which latter have now generally become too deeply submerged and too much shaded for rooting water-plants. Some of the lakes have lost large areas of rooted vegetation in the deeper parts, permanently, as it appears, while many others whose characteristic vegetation was killed out by the deeper water after the opening of the drainage canal, are now filling up again with the typical plants of deeper standing-water. This destruction of inshore and alongshore vegetation has been especially conspicuous in the broad belt of deadened trees and shrubs along the banks, especially in the middle course of the stream from Peoria southward. Other important effects are beginning to appear as these dead trees weaken and fall into the water of the stagnant lakes, fouling them, in the hottest weather, with the products of vegetable decay.

4. The greater depth of the present river, and especially the greater depth at low-water stages, must have an effect to diminish ranges of temperature, especially in the upper shallower part of the stream. The water there can not heat up as rapidly as formerly when exposed to the midsummer sun, or reach so high a temperature—a fact which must retard decomposition processes now as compared with the period before 1900, and thus delay the transformation of sewage materials into forms fit for use as food for the normal plants and animals of an unpolluted stream.

5. Along with the greater average volume of the stream goes necessarily an increased average rate of flow and a shortening of the time of passage of water from point to point and from the source to the mouth. This difference is greatest for the lowest stages of water and least for the highest, but our computations show that, at usual midsummer levels, only about half the time is needed for water to flow the length of the stream that was taken before the opening of the canal, about thirteen

days being sufficient for the passage from Utica to Grafton (230 miles) in the month of August in the years 1910–18, and an average of twenty-nine days in the same month of the years 1890–99.

This fact has many interesting consequences. Decomposition and assimilation processes set up at a given point and proceeding at a given rate are now extended farther down stream than formerly, and those which were usually completed at the mouth of the river before may now be only about half finished at that point. A plankton organism, if carried continuously by the main current, has much less time to multiply in the Illinois than formerly and reaches smaller numbers, and, other things being equal, it is proportionately less likely to be devoured on the way, the difference in this respect being the same as if the river were shortened by about one-half. Disease germs brought into the stream with sewage may now be carried as far again downward before they perish, and the sewage itself, imperfectly transformed before, as shown by chemical tests, now escapes from the river in still earlier stages of average transformation.

Of course neither plankton organisms nor any part of the water of the stream are actually carried the full distance down the main current, but everything is retarded more or less as it approaches the bottom or the shores. We have no data to show what the general average movement of the whole content of the river now is or how it compares with the former average rate of progress, but there can be no doubt of the general truth of the foregoing statement.

6. The sewage load of the river has greatly increased since 1899. This is a necessary inference from the growth of Chicago and the river towns and the completion of the intercepting sewer along the lake front turning into the canal all sewage formerly sent into Lake Michigan, and it is shown also by a comparison of chemical data. The chlorine content of a polluted water (mainly chloride of sodium or common salt) is the best chemical index to the degree of its contamination by sewage, since the chlorine compounds pass down stream virtually undiminished and unchanged, while the nitrogen is rapidly transformed, and presently drawn upon as food for plants. A comparison of the amounts of chlorine passing Averyville, just above Peoria, before 1900 and in 1914, gives us 2¼ times as much per second for the latter period.*

7. Notwithstanding the increase in the quantities of sewage coming into the river from Chicago, the flow of the stream has been increased in so much larger a ratio that the water of the river contained in 1914 a smaller *percentage* of sewage than before 1900. The sewage of the stream had become much more dilute than formerly.

The ratio of chlorine (parts per million) in the water passing Lockport, 35 miles from Lake Michigan, in 1897–99 compares with that of 1914 as 7.3 to 1, and the corresponding chlorine ratios for these periods at Averyville, 126 miles farther down, were as 2.3 to 1.

* The chlorine average at Averyville July to October, in 1897–1899, was 7.69 kilograms per second; in 1914 it was 17.31 kilograms per second.

8. Owing to the much greater volume of the main stream since 1899, the effect of tributary waters is now much less than before, whether this be the diluent effect of a cleaner stream than the Illinois, such as the Fox at Ottawa, or the polluting effect of a local inflow of sewage from one of the river towns, as at Pekin or Peoria. For the same reason these diluent effects are much less obvious and important at a high stage of water than at a low stage. Peoria sewage, for example, can not now pollute the stream at any time nearly as much as it formerly did when the river was low.

9. The present greater average depth of the stream and the consequent lower average temperature must retard somewhat the rate of spontaneous chemical change by which the proteid compounds of the raw sewage, quite unfit in that condition to serve as food for chlorophyl-bearing plants, become converted by successive steps into forms fit for assimilation by green plants—into free ammonia, nitrites, and nitrates, in sequence—and must carry these stages of change farther down the stream than formerly; and this effect is to be added to that due to a virtual doubling of the rate of the down-stream movement.

10. As a consequence of several of the foregoing considerations it follows that the uppermost part of the river was more heavily charged with organic matter before 1900 than in 1914, and this headwaters pollution diminished rapidly downwards, the river returning to practically normal conditions much farther up-stream.

11. In our earlier paper it was shown that the tumbling of the water over the dam at Marseilles had a marked effect in 1911 to increase the content of dissolved oxygen, the additional oxygen being obtained, of course, from the air mixed with the water by the fall; and it was also shown that this increase of oxygen differed with the stage of water in the stream, being greatest when the river was low and the head of the falls was consequently highest. From this it follows (although we have no data on the influence of the dams before 1900) that this oxygenating effect must have been greater at the relatively low stages of that period than it is now. The removal of the upper dams, especially that at Marseilles—a measure strongly advocated in the interests of navigation—would have the effect to carry the polluted waters farther down-stream and to postpone their renovation both in distance and time.

12. It is also obvious, from what has already been said, that the organic contents of the sewage, unfit, as they are delivered to the stream, to serve at once as food for its normal clean-water animals and plants, must become first available to them farther down-stream than before, and that, as a consequence, such normal organisms will find themselves excluded, at least at times of greatest pollution, from parts of the upper river where they have previously found food. Just how far down-stream this change of conditions has progressed is a question difficult to answer exactly, especially as we have no collections of aquatic plants and animals from the upper river made before 1900 in a way to bring them into comparison with those made by us since that date and thus to give us direct

evidence on this point; but to come to conclusions it is only necessary to assume that chlorophyl-bearing organisms presently arrive in the river whenever conditions appear favorable to their maintenance and multiplication, an assumption warranted by all our studies, and those of others, upon the river and elsewhere and at other times. Such conditions occurred in their *earlier phases* between Lockport and Morris before 1900 at low water; but in 1911 not until somewhere between Marseilles and Spring Valley; while *optimum conditions* for green plankton apparently occurred at or above LaSalle before 1900, but in 1911 not much if any above Chillicothe, and in 1918 not much above Peoria.

More recent evidence of a still continued gradual creeping down-stream of pollutional conditions is found by comparison of collections made in 1911 with those obtained in August, 1918. In the former year a foul-water fungus *(Sphaerotilus natans)* disappeared from both channel and shore at or near Starved Rock, while August 28 to 30, 1918, it was found in the river at Henry, 35 miles below Starved Rock, and also at Lacon, 6 miles still farther down. At Henry, it was quite healthy, with normal cell-division in progress.

Other evident indications are given by collections of two Lake Michigan diatoms *(Tabellaria flocculosa* and *T. fenestrata)*, which come into the river through the sanitary canal. In 1910 these clean-water plants managed to survive in small numbers, as they passed down-stream, but were always of a pallid, sickly color until they reached Chillicothe, and here the water was clean enough to permit their return to normal condition and to a rapid rate of multiplication; while in August, 1918, their numbers declined steadily down-stream, until at Pekin they disappeared almost completely.

Another Lake Michigan diatom *(Melosira granulata* var. *spinosa)* which lived through the worst pollution of 1910 and began to multiply at Spring Valley, does not now do so until it passes Chillicothe, 36 miles farther down.

13. Consistenly with the foregoing statements, the ratios of total nitrogen, whether expressed by parts per million or as kilograms per second, now escaping into the Mississippi River are larger than they were in 1899. The nitrogen ratio at Grafton in 1899 was to that of 1914 as 1 to 1.60 in the spring months (April to June), and as 1 to 1.26 in the summer months (July and August); and in kilograms per second these ratios in 1899 were to those of 1914 as 1 to 3.46 in spring and as 1 to 4.83 in summer. In other words, between 1899 and 1914 the total nitrogen *in a given quantity* of the river water was increased by about one-fourth in spring and by six-tenths in summer, while the total for the *entire flow* of the stream *in a given time* was, in spring, 3½ times as great in 1914 as in 1899, and in summer about 4.8 times as great. The nitrates, on the other hand, at the mouth of the river were, in parts per million, as 1 in 1899 to 1.48 in 1914. It would seem from this that the nitrogen-consuming organisms have not increased in quantity since 1899 as fast as their food supplies.

14. These food supplies show increase not only at the mouth of the river, where they are no longer available to the organisms of the stream itself, but also in the middle course of the Illinois, where its principal fisheries are found. The sum of the nitrates in spring, summer, and fall was greater in this part of the river in 1914 than in 1899—at Havana by 46 per cent., at Beardstown by 39 per cent., and at Meredosia by 40 per cent.

15. That this greater food supply has resulted in a greater production of plant and animal life in the stream was to be expected, and such evidence as we have supports this expectation. As we have shown in the earlier paper already cited, the larger plankton organisms of the Illinois River at Havana in 1909 and 1910 surpassed in quantity to the cubic meter of water that of 1897 and 1898 by 69 per cent., and surpassed the average production of the three years from 1895 to 1898 by 135 per cent., while the like plankton of 1909 and 1910 from Quiver Lake, a bay opening broadly into the river at all stages, surpassed that of the earlier period by 218 per cent. Furthermore, collections of the animal forms of the river bottom, so made at many points down the course of the stream as to give the number of specimens to a square yard, show us that the richness of the plankton and that of the bottom sediments rise and fall together, the part of the river containing the largest number of organisms from one containing the largest number from the other also. We consequently have reason to believe that the bottom organisms, from which many animals, fishes especially, obtain an important part of their food, are more abundant now than before 1900.

It is to be noted, however, that these foregoing data of plankton production were obtained at a time (August, 1909, to August, 1910) when only about 25,000 acres of bottom-land were under levee, and that this area has now been increased some five or six fold; and it will presently be shown that plankton production must be expected to fall off rapidly with the draining of lakes and a reduction of the area of overflow. It is quite possible, therefore, that the increased plankton production due to the increase of sewage has now been lost as a result of reclamation operations.

16. The area in the Illinois bottom protected by levees from overflow and thus reclaimed for agriculture, increased between 1899 and 1914 from 6,700 acres to 124,205 acres, and there were at the latter date 47,250 acres more in drainage districts whose levees were not finished at that time. When these newer districts are completely leveed and drained, the original area of overflow of every spring will be reduced by 39 per cent., and that subject to overflow at the high-water level of 1904 will be reduced by 42 per cent. The effect of this restriction of overflow upon some of the tendencies due to the opening of the sanitary canal must be considerable. The river will now rise higher than before in times of flood and will fall lower when rainfall is deficient, but the floods will run off more rapidly since the leveed areas which were formerly flooded will no longer help impound the waters of the overflow, giving them up gradually to the stream.

Owing to the confinement of flood waters within narrower bounds, all effects of greater depth and swifter flow of the stream must be intensified. The bottom sediments are now more forcibly scoured out and moved farther down-stream than formerly; the successive stages of the oxidation and assimilation of sewage proteids are carried farther downward, as is also the upper limit of the normal life of the stream; the plankton is transported more swiftly and continues a shorter time in the Illinois, multiplying there, consequently, to smaller numbers; and more of the food material of the Illinois escapes into the Mississippi unconsumed.

Moreover, drainage of contributing lakes and swamps and narrowing of the area of overflow lessens the productivity of the river itself quite independently of the richness of its waters in the elements of fertility. A river and its plankton are a flowing soil and its crop, both slipping away continuously, but both renewed constantly from an exhaustless source of supply. The fertility of the flowing water at any time is not dependent on the fertility of that which has preceded it, but on materials of fertility brought into it from the watershed. A complete exhaustion of this flowing soil by "overproduction" would not impoverish, but would actually enrich the organisms depending on it, for they could avail themselves of its entire product without penalty of subsequent starvation.

As the plankton of a river system is carried down-stream, its progeny are carried with it, and, however numerous they may become, they can have no upstream effect on the population. If the running water were left wholly to itself, the river would speedily empty itself of plankton; to maintain the floating population there must be a constant source of supply outside the waters involved in the downward movement. Such a supply can be found only in places where aquatic organisms are virtually stationary, or from which, to say the least, they do not escape until they have themselves begun to multiply, and in which, consequently, they will leave fertile descendants behind them. Such places of possible continuous origin of the plankton organisms are weedy waters along shore, sluggish shoals, eddies, bays, sloughs, open backwaters of the bottom-lands, and lakes connecting with the stream. The river plankton originates in the mere overflow of the stationary population in such breeding places, and the reduction of these sources of supply must have its proportionate effect on the river product. Hence, the plankton productivity of the stream does not depend primarily on the richness and extent of its own flowing waters, but on those of its subsidiary breeding grounds, and if these are not adequate to the maintenance of a plankton sufficient to consume all the readily available food materials of the stream, more or less fertility of the current waters must go to waste.

It is conceivable, of course, that stagnant and semi-stagnant tributary waters might be so productive and so extensive as to contribute to the river a rapidly multiplying population sufficient completely to exhaust the food supply borne by the running water within the limits of its own course, however fertile it might be, sending it out at the mouth of the

stream with all the elements of its fertility strained out; but such a self-contained and self-sufficient system is far from anything we actually find, and there must be a heavy loss of potential productivity at the mouth of every normal stream.

It may be noted, however, that a river, notwithstanding its continuous losses, may actually maintain a heavier plankton than a lake, even where both derive their food materials from the same source, as from the waters of a spring flood. The river being continuously fertilized while the lake has only the fertility left to it when the flood subsides, if the former has a slow current, as in low water, and a long course, its plankton may multiply to a number which the fixed fertility of the lake can not maintain.

Effects on the Fisheries

The apparent effects upon fish production of some of the environmental changes here discussed were treated in considerable detail in 1913 in our paper on the biology of the upper Illinois River. In this it was shown that the fishes normal to the river were virtually driven out of it during the midsummer low water of 1911 and 1912 by pollutional conditions extending as far down as Ottawa, 34 miles from the source, and that it was not until Hennepin was reached, 32 miles still farther down, that the fish population of the river was made up of substantially the same species as were to be found farther down. It was, however, in the Henry-Chillicothe section of the river, 77 to 93 miles down-stream, that the relative numbers of the several species first became virtually normal, and that all ichthyological effects of the Chicago contamination had obviously disappeared.

After the above paper appeared we compiled statistics of production for the whole river from every available source, and these were placed, in 1915, at the disposal of Alvord and Burdick, civil engineers, who were making at the time for the Rivers and Lakes Commission of the state an extensive study of the Illinois River and its bottom-lands with special reference to problems of fisheries, agriculture, and flood control. Their report on the status and possibilities of the river fisheries embodies substantially all our information bearing on the subject at the time, and we find their reasoning convincing and their conclusions sound. Our objects and point of view are, however, somewhat different from theirs, and we find it necessary to develop some parts of the discussion more fully than was done by them in their report.

That the actual harvest of the Illinois River fisheries was greatly increased from 1900 to 1908 as compared with the yield from 1894 to 1899 is shown by statistics collected by the Illinois Fishermen's Association, the Illinois State Fish Commission, and the U. S. Bureau of Fisheries; but that a marked decline of production followed, at least until 1913, is made evident by data of shipments from Havana, one of the principal fishing points on the river, obtained by the junior author of this paper for the six years following 1907. From 1894 to 1899 the

yield of the river fisheries rose from 6,037,378 pounds to 12,605,691 * pounds—with an average annual yield of approximately 8,900,000 pounds; and between 1900 and 1908 inclusive it rose from 11,899,865 pounds to 21,583,000 * pounds, with an annual average of approximately 15,000,000 pounds. The increase for the five years immediately preceding the opening of the sanitary canal was thus about 9 per cent. per annum, that for the 8-year period following the opening was about 3.5 per cent. per annum, and the estimated *decline* for the next four years based upon statistics of production at Havana was at the rate of 15 per cent. per annum. The fisheries at this point yielded in fact 25 per cent. less in 1912 than they did in 1896; the gain made in the course of this period of sixteen years was more than lost before its close.

There are four factors to which this rise and fall of production may be attributed: 1, the opening of the sanitary canal and the diversion of nearly all the Chicago sewage from lake to river; 2, the rapid multiplication of the European carp, which by 1908 yielded 64 per cent. of the whole product of the river fisheries; 3, the great stimulus to fishing which this enormous increase of the carp produced; and 4, the rapid progress of reclamation operations from 1908 onward. The first three of these factors tended to increase the actual yield, but the last, a cause of decline, has more than overbalanced their joint effect. It is difficult to isolate these various factors in a way to distinguish their separate shares in this stimulus to production or the reverse, but something may be done in this direction by an examination of such statistics as are available.

The principal multiplication of carp came between 1894 and 1897, when this fish rose in ratio from 9.6 per cent. to 56.5 per cent. of the entire catch from the river; and the carp continued in about this ratio of abundance until 1903, when it stood at 54.9 per cent. Our next data are those for 1908, when the entire catch from the river, as given by the U. S. Bureau of Fisheries, was 24,000,000 pounds, of which 64.4 per cent. were carp, the total yield of both carp and other fishes being more than twice that reported for any preceding year. The year 1908 was, however, so exceptionally favorable for fishing that its totals are misleading; but the rise in ratio of carp to other fish seems nevertheless correct.

It is evident that it is to the increase of carp more than to the influx of Chicago sewage that we must attribute the rise in production after 1894. From that year to 1899 (the period of rapid multiplication of carp) the fisheries' yield of the river increased 2.1 times, while by 1907, seven years after the opening of the canal, it had risen only to 14,739,000 pounds—an additional gain of 17 per cent.

This latter increase may have been due to a greater food supply derived from the sewage, or it may have been simply a consequence of the growth of the fishing industry, which was greatly stimulated by the increase of the carp supply.

* The mean of the estimates of the U. S. Fish Commission and of the Illinois Fishermen's Association.

As will be seen from the table on this page, the number of men engaged in fishing in the *State* of Illinois increased 42 per cent. between 1894 and 1899 (five years) and 86 per cent. between 1899 and 1908 (nine years), and the value of the fisheries equipment increased 20 per cent. during the first period and 194 per cent. during the second. The value of the fisheries product, on the other hand, increased 157 per cent. and 151 per cent. during these two periods, respectively. We have no separate data for the *Illinois River* for 1894 or 1899, but in 1908 more than half the fisheries of the state and nearly two-thirds of the capital employed in fishing were on that stream.

STATISTICS OF FISHERIES IN ILLINOIS, 1894–1908 *

PERCENTAGES OF INCREASE OR DECREASE

	Between 1894 and 1899		Between 1899 and 1908	
	Per cent. increase	Per cent. decrease	Per cent. increase	Per cent. decrease
Men employed (numbers)	42	.....	86	
Equipment (values)	20	.....	194	
Fisheries products (pounds)	157	.....	151	
Black bass	30	.....	322	
Buffalo-fish	.....	31	.....	29
Carp	1051	.....	119	
Catfish	.....	19	30	
Crappie	112	.....	260	
Sheepshead	.....	45	9	
Eels	.....	34	6	
Paddle-fish	43	.....	106	
Pike	.....	14	.....	38
Sturgeon	83	.....	13	
Suckers	.....	38	8.5	
Sunfishes	159	.....	216	
Wall-eyed pike	.....	62	.....	52
White, yellow, and rock bass	6	.....	.....	92
Perch †	30	.....	1040	
All native fishes	42	.....	.....	11
Bottom feeders	.....	29	.....	7

* In 1908, 57 per cent. (2,500) of the fishermen of the state and nearly two-thirds ($551,000) of the capital employed, were on the Illinois River.

† Mostly from Lake Michigan district.

A comparison of the percentages of increase and decrease in the two periods covered by the above table, one of five years and the other of nine, shows that the average rate of increase per annum in number of men was a little greater in the second period than in the first, and that of equipment was more than five times as great; but that, nevertheless,

the rate of increase in the product of the fisheries was but little more than half as great in the second period as in the first. In other words, the product of the fisheries fell far short of keeping pace with the increase in men and means devoted to fishing. This fact indicates that the stream was being "over-fished" during the second of the above periods, and that its yield must consequently be expected eventually to fall off if fishing operations are continued on the same scale as in the years just preceding 1909.

This "diminishing return" for increasing activity is seen especially in the yield of European carp, as was to be expected in view of the recent introduction of this fish into waters especially favorable to its growth and multiplication; but it is also seen in the yield of the *native* species, which after *increasing* at an average annual rate of 8 per cent. for the first or five-year period, *diminished* about 1 per cent. per annum during the second period. That is, the rapidly growing abundance of carp so stimulated fishing operations that the stock of native fishes was too heavily drawn upon and began to dwindle in yield. We see this particularly in the species which are distinguished as bottom-feeders—the buffaloes, the suckers, the sturgeon, the sheepshead or drum, and the catfishes.* Taken together these diminished in yield about 6 per cent. per annum during the first period, and nearly 1 per cent. during the second.

In comparing these two periods, account should be taken of the fact that 1908 was an especially favorable year for fisheries, and its yield was far the greatest ever known on the Illinois River. In that year the fishing season, which begins with July and extends to November, was one of low water, concentrating the fish in relatively close quarters, and giving easy access to the fishing grounds, and this fishing season had been preceded by a long period of unusually high water, covering nearly all of 1907 and the early months of 1908, during which the fishes had a wide range over shallow waters filled with an abundant food supply. The consequence was a fisheries yield 50 per cent. greater than the average of the five years next preceding of which we have records, viz., 1899, 1900, 1903, 1906, and 1907; and to make a just comparison between our two periods in respect to increase or decrease of yield the yield of 1908 should be diminished by one-third. If this be done, the ratios will stand as tabulated on page 152.

Along with an enormous multiplication of the carp in 1894 to 1897 the yield of native fishes fell off *in the Illinois River* by 22.2 per cent. (from 5,457,731 pounds to 4,234,308 pounds); * but from 1900 to 1907 it increased by 56 per cent. In other words, as the number of carp increased the number of native fishes *diminished* before the opening of the sanitary canal at an average rate of 7 per cent. per annum; and after the opening of the canal, the number of carp remaining virtually constant, the supply of native fishes *increased* in seven years by an average of 8

* The yield of these bottom-feeding species in 1894, when the number of carp was as yet relatively insignificant, was 81 per cent. of the total yield of native fish.

* Alvord and Burdick, Fig. 25.

PERCENTAGES OF INCREASE OR DECREASE BETWEEN 1899 AND 1908 (ADJUSTED)

	Per cent. increase	Per cent. decrease
Fisheries products (pounds)	68	
Black bass	181	
Buffalo-fish	.....	47
Carp	46	
Catfish	.....	13
Crappie	14	
Sheepshead	.....	27
Eels	.....	30
Paddle-fish	37	
Pike	.....	60
Sturgeon	.....	25
Suckers	.....	28
Sunfishes	110	
Wall-eyed pike	.....	67
White, yellow, and rock bass	.....	94
Perch	695	
All native fishes	79	
Bottom-feeders	.....	37

per cent. per annum—a condition of things not easily understood except on the hypothesis that the resources of multiplication and subsistence opened up by the canal had enabled the native river fishes not only to sustain themselves but to increase in number in the face of the tremendous competition of a quantity of carp greater than that of all the other fishes of the river taken together.

To what extent, if at all, it was the great and increasing quantity of organic material brought into the river by the canal which was the cause of increasing fish production, or whether the cause was mainly or wholly an expansion of the area of shallow water in which fishes could breed and feed to the best advantage, is a question to which we are unable to make definite answer; but it is certain that it is now the area of available breeding and feeding grounds, and not the food supply, which is the limiting factor in the yield of the Illinois River fisheries. The raw materials of food sufficient for a much greater volume of plant and animal life than the river and its dependent waters now contain, are being continuously poured into the stream and worked up to the chemical conditions required for their assimilation; but they pass out of the river at its mouth in increasing quantities unassimilated because, owing to the progressive diking of bottom-lands and draining of lakes, the productive area is steadily diminishing. From the report of Alvord and Burdick it appears that up to 1899 the area of the bottom-lands under completed levees was but 9,100 acres; five years later it had risen to 21,500 acres; by 1908, the year when the fisheries data of the last national census were collected, to

54,850 acres; by 1913, when our own last data of fish production were obtained, to 130,830 acres; and a year later, when Alvord and Burdick prepared their report, to 145,780 acres. Furthermore, there were at this time about 50,000 acres in drainage districts proposed or already formed, in which the work was in various stages of advancement, besides 7,755 acres concerning the condition of which our information is incomplete—a total of 200,000 acres of Illinois River bottom-lands covered by levee districts acually complete or in immediate prospect four years ago.

The *land* area overflowed by the extraordinary high water of 1904 amounted to 280,910 acres, and if we add to this 49,340 acres in bottom-land lakes at low-water stages, we have a total of 330,250 acres, outside the area of the stream itself, formerly covered by water in time of flood. From 44 per cent. of this area the fishes of the river were already permanently excluded in 1914, and another 16 per cent. will be added to it as soon as the drainage projects then in hand or in immediate view are completed.

Coincident with this restriction of their range the yield of fishes declined, as shown by our data of shipments from Havana from 1908 to October, 1913, as shown in the following table.

TOTAL FISH CATCH, HAVANA MARKET

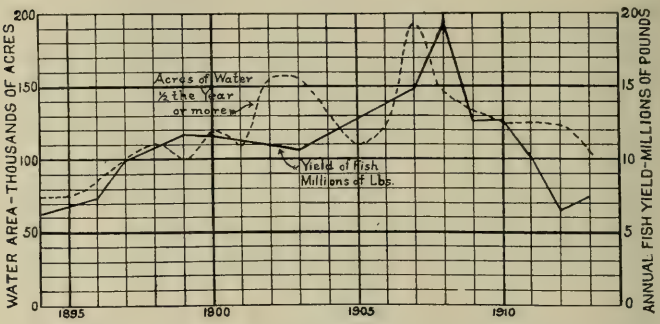
Year	Pounds	Per cent. of total catch on river	Authority
1896	1,573,298	21.7	Illinois Fishermen's Association
1897	1,600,183	16.5	" " "
1899	1,830,291	16.3	" " "
1900	1,368,010	11.4	" " "
1907	2,700,000	18.4	Illinois Fish Commission
1908	3,800,000	19.7	" " "
Average	.....	17.3	
1908	3,066,658	.....	R. E. Richardson
1909	2,223,794	.....	" " "
1910	2,221,930	.....	" " "
1911	1,803,724	.....	" " "
1912	1,181,151	.....	" " "
1913 (to October 31)	1,293,563	.....	" " "

NOTE.—1,593,000 pounds average 1896 to 1900 inclusive.

All the facts indicate that the relation here shown is one of cause and effect—that the yield of fishes is diminished, in the face of a greatly increased and rapidly growing supply of the raw materials of their food, because of the narrowing of the backwaters, which are for the river important places of digestion and assimilation in which the organic wastes of the city and of the land are worked up into forms fit for food for the higher animals. It is not only space but time also that is now lack-

ing, since the river now hurries its burden downward at a rate more rapid than it did before it was shut out from so large a part of its valley.

This correlation of production with the area of overflow is well brought out by Alvord and Burdick in the following diagram showing the relation, from 1894 to 1914, between the yield of fishes from the Illinois, on the one hand, and the area of the river valley which was under water for half the year or more on the other.



"That the various important changes in the river environment should take unequal effect on the various species of fish, is of course to be expected. Those most sensitive to pollution will be the first to disappear from the upper river as pollution increases and the last to reappear as one goes down the stream. As the river fisheries are now directed chiefly to the catching of carp, native fishes of similar range and habits to the carp are most likely to be taken in excessive numbers and to dwindle year by year as a consequence; and as the ratio of shallow alongshore water to the deeper parts of the river and lakes is diminished by diking and draining of bottom-lands, the species which feed and breed alongshore will feel the effects of the change most deeply. In our collections of 1911 and 1912 a single minnow known as the shiner *(Notropis atherinoides)* was especially notable for its indifference to pollution, and this was the only fish found in the main current in midsummer, in more than accidental frequency, as far up the stream as Marseilles, 26 miles from the source. A number of other species were taken at this place, it is true, below the dam, but only at the mouths of small tributaries which were diluting the river water with a cleaner flow. At Ottawa, 34 miles from the source, single specimens of gizzard-shad, red-horse, and European carp were taken from the undiluted river among 79 fishes captured in various ways, 69 of which, however, were the shiner above mentioned. At Starved Rock (42 miles), the black bullhead and the large-mouthed black bass were added to the list, and at Hennepin (66

miles) the short-nosed gar, the dogfish or bowfin, the common sucker, the speckled bullhead *(Ameiurus nebulosus)*, the bluegill sunfish, the black crappie, and the warmouth (Chaenobryttus) were represented by one to three specimens each in hauls which gave us 174 European carp. The common perch, both the crappies, and the large-mouthed black bass began to appear in some numbers at Depue (60 miles), but not in their normal ratio much above Chillicothe (93 miles).* The larger and more voracious game fishes, such as the wall-eyed pike and the pickerel, which had disappeared above Peoria, seem never to have been normally abundant in the Illinois. The most notable species whose numbers have fallen off greatly of recent years in the main middle course of the stream (Pekin to Meredosia) are the shovel-fish or spoonbill cat, the buffalo-fish, and the sheepshead or drum.

On the whole, the general make-up of the river population of fishes has been surprisingly little affected by any of the recent events here discussed excepting, of course, the introduction of the European carp.

Investigation Needed

The total effect of reclamation operations upon the important fisheries of the Illinois is so serious as to call for a careful study of the possibilities of prevention and remedy; and this is the conclusion reached by Alvord and Burdick in their report to the Rivers and Lakes Commission. After calling attention to the fact "that the fishery of the Illinois River is more valuable than that of any other fresh-water river fishery in the United States, and is exceeded only by the Great Lakes and the salmon industry of the Pacific coast," and that, owing mainly to reclamation operations, the yield of the river has lately been reduced to about a third that previously reported, they say: "It would seem, however, that there is prospect of a good profit by intelligent fish culture in the ponds and water courses remaining within the levee districts, provided that the industry is carried on as an adjunct to farming in much the same way that poultry is ordinarily raised upon the farm. This would utilize a water acreage that otherwise could produce no revenue and could serve no useful purpose except to store the flood waters in the course of passage to the drainage ditches. If the fishery is to remain commercially important, means must be provided to take the place of the breeding grounds formerly furnished by the shallow waters of the lakes and sloughs which have been reclaimed.

* * * * * * *

"It is believed, notwithstanding the levee districts present and future, that a scientific utilization of the remaining public waters, including the river and twenty or more meandered lakes, together with the best use of the remaining undiked bottoms and the spaces between the river banks and levee toes, will result in the maintenance of a valuable fishery. We

* The field party already referred to, which made the survey of the river from Hennepin to Peoria in August and September, 1918, saw no signs of fishes in the river at either Hennepin or Henry, and were told by fishermen that none had been seen for a long time at either place. At Lacon one had been occasionally noticed in the river channel.

recommend that the State Laboratory of Natural History * be empowered to investigate and determine the best means for promoting the fishery interests in the public waters and the adjacent undiked lands. We should hope that a practical program might be worked out that would permit of great help to the fisheries and at the same time provide game and fish preserves, usable by the public under proper restrictions."

Such an investigation should include problems relating to both public and private waters, the former comprising the river and its principal tributaries and the bottom-land lakes which are not protected by levees and are hence subject to overflow, and the latter the lakes within levee districts which lay too low or were in part too deep for profitable drainage. There are serious difficulties connected with the utilizing of these last-mentioned waters, owing to the fact that they are, as a rule, mere mud-holes, without shallow margins and with bottoms deep with an almost impalpable ooze. Only intelligent experiment can show whether they can be so dredged as to give them bottoms of reasonably firm consistency, and whether, by adjacent excavation, fertile shallows can be created as breeding grounds for adult fishes and feeding grounds for the fry. That the condition of the river and meandered lakes could be greatly improved by carefully considered management as a public fisheries property there can be little doubt, but the problem of methods of operation and policies to be adopted in such a case is a new one, for the solution of which there are no precedents. As a fisheries property the waters of the state are an unsubdued and neglected wilderness, and the investigator in this field must be prepared to do a pioneer work.

* Now the State Natural History Survey.

ARTICLE VII.—*The Pentatomoidea of Illinois, with Keys to the Nearctic Genera.** BY CHARLES ARTHUR HART.

INTRODUCTORY

In 1898 Prof. H. E. Summers prepared the first key in English to the American pentatomid genera * *, using the collection of the Illinois State Laboratory of Natural History (now Division of Natural History Survey). The key was based on Stål's keys, but, as Van Duzee says, "contains much original work." It seems appropriate that this collection, greatly increased since 1898, and that of the University of Illinois should now serve for a revision of the subject. In identifying species and constructing keys to them, Van Duzee's "Annotated List" † has been of the greatest value. In the general grouping I have agreed closely with Kirkaldy's views.‡

The commoner species form homogeneous groups and are easily disposed of in keys, but there are a number of rare and little-known species, scattered representatives of important exotic groups, to which I wish to direct especial attention—although their inclusion complicates the classification—in order that further knowledge of them and their distribution, either in Illinois or elsewhere in the United States, may be particularly searched for.

In the arrangement of my keys I have tried to show the natural grouping and succession, because I believe that an artificial grouping, although apparently simpler, often obscures or suppresses the more difficult yet essential points of difference, and is of little value in the extension of knowledge. In characterizing groups, I have not necessarily taken into account extralimital forms. The term "segment" is often to be understood after such combinations as second antennal, rostral, tarsal, etc.; and the words dorsal and ventral, similarly used, refer to the abdominal segments. The term "elytra" is used as a convenient term for thickened opaque fore wings generally.

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* The manuscript of this paper was only partially complete at the time of Mr. Hart's death. Its final preparation was undertaken by J. R. Malloch, and where additions to the original are made, whether in the form of records of species, or notes, or amplifications, these are indicated by brackets, either in the regular text or in footnotes.

* * Proc. Iowa Acad. Sci., Vol. 6, p. 40.

† Trans. Am. Ent. Soc., Vol. 30, No. 1. [Van Duzee's Catalogue of Hemiptera (Univ. Cal. Pub., Tech. Bul. Coll. Agr., Agr. Exper. Sta., Vol. 2, 1917) appeared but a short time before Mr. Hart's death, and synonyms therefrom have in some cases been added to the paper by the editor. The citations to original descriptions are also additions by the editor, nearly all of them being made direct from the publications in which the descriptions occur, the above-named catalogue serving admirably, however, as an aid in locating them.]

‡ Cat. Hemip. (Heter.), with Biol. and Anatom. References, p. 363.

The subfamily Tessaratominae, although usually placed last, seems to me to be a quite generalized group, with the first visible ventral (really the second) widely exposed, so that its spiracle is not beneath the metasternum nor just at its edge, but is an appreciable distance away from it. The elytral venation, which in most Pentatomidae is very obscure, is here easily traceable. Some of its genera are extremely close to our Pentatominae; others, in rostral structure, approach the Asopinae; others, in the venation of the hind wings, suggest the Cyrtocorinae. This subfamily forms an important group in the Old World, and is also represented by a few species in Mexico and Central America, some of which may at any time be found within the southwestern boundary of the United States; for this reason, and since this interesting group is often represented in general collections, I have included it in the key.

My thanks are especially due to Dr. S. A. Forbes, and to my colleague, Mr. J. R. Malloch, for their friendly encouragement and cooperation.

MISCELLANEOUS NOTES

The Pentatomoidea with slender beaks are normally plant feeders, although some of these, such as Euschistus, are sometimes seen sucking the juices of small insects. Some species, as Murgantia, are well-known pests; but the majority do little damage to plants. The strong-beaked forms are predaceous, and some are appreciably helpful in reducing the numbers of injurious insects, feeding upon larvae of the tussock-moth and similar species.

The species are probably mostly single-brooded, the nymphs occurring in spring and early summer and becoming adult as the season advances, very much as in the Acrididae. Many species hibernate as adults, and may be found among fallen leaves in winter or on vegetation in early spring. Horse-chestnut underbrush is a favorite shelter for Euschistus at this time. Some species are limited to particular food-plants, but many of them, especially the predaceous kinds, are widely scattered.

When heteropterous nymphs are pinned directly from the killing-bottle, the soft integument generally shrivels and curls in drying, and becomes more or less blackened because of interior decomposition, in which condition they are truly unsatisfactory objects for study. This trouble is avoided in most cases by leaving them in strong alcohol for a few weeks before pinning. This sterilizes and coagulates the tissues, specimens drying with all the fine color-patterns clear and distinct, and seldom showing any noticeable change of form, making attractive and interesting additions for a collection.

Adults may be pinned from the cyanide bottle, or they may be killed in alcohol without injury, perhaps with benefit, if not left in it more than a day or so. Specimens should be pinned through the scutellum near its anterior margin, preferably a little to the right of the median line. The waxy or greasy material that sometimes appears on them is easily removed by means of benzine or alcohol.

The sexes are usually recognized, as in all other Hemiptera, by the structure of the venter beyond the sixth segment. In the male there is only a single plate or capsule, open posteriorly, rarely transversely divided; in the female, the basal part is divided medially into two plates, while the apical part shows several small plates. The median division in the female is the most conspicuous difference. Secondary sexual characters are rarely seen. In Amnestus the distinction is very difficult, but in this genus there are interesting secondary sexual characters consisting of peculiar spines on the fore and hind femora, and differences in thoracic sculpture, which are indicative of the sexes.

[The general appearance of some of the commoner species is well represented in Plate XXI, Figures 78 to 83 inclusive.]

Classification

Kirkaldy believed that the pentatomids were the most primitive Heteroptera, and I am inclined to agree with him. Probably the Ochteridae represent a generalized stem, as Reuter suggests, but I believe that the five-segmented antennae of the pentatomids is older than the four-segmented of other families, and is not a case of specialization, even though the antennae of pentatomid nymphs is uniformly four-segmented.

The venation of the Coptosomidae is by far the most generalized in the Pentatomoidea studied by me; yet, singularly enough, the scutellum would seem a climax of specialization. The Scutellerinae come next in wing venation, leading to the Pentatominae, along with a reduction in the size of the scutellum. In the Pentatomidae, the development of ventral spine and sternal ridge would seem to begin in the subfamily Pentatominae in such forms as Banasa, Nezara, and Arvelius, with the Acanthosominae and Asopinae as offshoots, and lead up naturally through the Edessinae to the Tessaratominae. Yet the venational evidence shows that this order must be reversed.

The most primitive type of heteropterous caecal structure I should consider to be the one with the largest number of rows and pockets, specialization proceeding by numerical reduction and differentiation, frequently reaching complete elimination, as in Asopinae. The data are as yet very incomplete, but it is evident that the four-rowed type, found in the scutellerids and pentatomids, should precede the two-rowed type, represented by the Cydnidae, *sens. lat.*, and succeeding families. In the four-rowed series Brochymena, with its large number of caecal pockets and its well-developed wing hamus, is clearly primitive.

THE IMAGINES

The Caecal Appendages

Much light has been thrown on pentatomid relationships by the interesting studies of Dr. H. Glasgow * on the caecal pockets of the Heteroptera. His paper appeared in a general biological publication. It was primarily a study of the symbiotic bacteria always inhabiting these

* Biol. Bul., Vol. 36, p. 101, pl. I–VII.

caecal pockets, and the caecal structures themselves were but briefly treated. Dr. Glasgow hopes to continue these studies, and will be very glad to examine fresh specimens, living, if possible, of any additional species; in the meantime he has very kindly placed at my disposal the unpublished details thus far obtained by him on this subject.

In the Halydinae, genus Brochymena, he found between the third stomach and the rectum an elongate intestinal tract bearing four equal and equidistant rows (two opposite pairs) of numerous close-set finger-like caecal pockets, about 400 in each row. In all the Pentatominae, Scutellerinae, and Graphosomatinae examined, he found the same structure uniformly present, except that the number of pockets in a row was less, varying from 70 to 220. The largest numbers in the Pentatominae were in Nezara (220), Euschistus (190), and Murgantia (160); the smallest, in Solubea (70), Hymenarcys (75), Cosmopepla (75), and Peribalus (90). Thyanta, Mormidea, Coenus, and Proxys were intermediate (110–125). The Graphosomatinae were represented by *Podops cinctipes* (75–80), and the Scutellerinae only by *Homaemus proteus* (105–110).

A second type of this structure was found in the Cydnidae, Coreidae, Pyrrhocoridae, and certain Lygaeidae. Here there is only one pair of opposite rows, without the slightest trace of the other two of the first type. The number in each row varied greatly in different genera. In the Cydnidae the number was not large—65 in Sehirus (Cydninae) and 75–90 in Thyreocorinae; in the Coreidae there is a quite regular descending series, from 775 in Archimerus and 650 in Metapodius to 155 in Catorhintha, 125 in Alydus, and none at all in Stachyocnemis and the Rhopalinae; and in the Pyrrhocoridae, Largus had 135, while Dysdercus had very few—only six in the female and none at all in the male. The Lygaeidae show a decided tendency to reduction and specialization. In the Pachygronthinae there are again two rows; in *Oedancala dorsalis,* 31 in each row, rather loosely spaced and oval; in *Phlegyas abbreviatus,* about 29, long and narrow and closely placed in two short rows, but the last pair in the female is greatly enlarged. In most other Lygaeidae and in Berytidae [= Neididae] a third type of this structure appears, evidently a modification of the previous type. In this type there are very few pockets, more on one side than on the other, and the pockets of each side are bunched together in one or two groups on a common basal connection. In Myodochinae and Blissinae there are on one side two groups, each of 3–12 pockets; and on the other side, only 2–7 pockets in all, usually in a single group, rarely in two. In the Berytidae [= Neididae] there is only a single group on each side, the number of pockets on each side in *Jalysus spinosus* being 6 and 9 respectively in the example studied.

In making these studies, often many individuals of a species were examined, and the variation within a species was found to range from 4 to 18 per cent. of the total number, being usually about 10 per cent.

In the remaining groups examined, related to those mentioned, as well as in all the other Heteroptera, the structure was found to be entirely

wanting, the third stomach being sessile on the rectum without any intervening tract. This was the case in the Asopinae, represented by Apateticus and Perillus; in the rhopaline coreids (Serinetha, Corizus, and Harmostes), also in Stachyocnemis of the Alydinae; in the male of Dysdercus; in the Lygaeinae (Nysius, Lygaeus, and Oncopeltus), Cyminae (Ischnorrhynchus), and Geocorinae (Geocoris); in all Tingitidae and Aradidae (Corythucha, Piesma, and Aradus); and in representatives of many other heteropterous families examined.

The Wing Venation

The chitinized corium and differentiated membrane of the fore wing, as well as the wing folds in both wings, have greatly obscured the venation in the Heteroptera, and retarded its use in systematic work. Comstock and Needham, in the "Wings of Insects," Chapter III,* have figured the tracheation of the fore and hind wings of a pentatomid nymph, and the venation of a coreid fore wing. The pentatomid was not reared to the adult stage; but this is hardly essential, as the venation is very similar throughout the family.

In the fore wing of *Menecles insertus* (Pl. XVI, Fig. 1) the venation is unusually distinct for one of the Pentatomini. The folds or furrows are indicated by two fine impressed lines. One of these is nearest the costal margin, and does not reach the membrane. The veins are indicated by smooth, raised, pale lines. The one in front of the anterior furrow represents subcosta and radius united. At the end of the furrow, the radial sector branches abruptly off toward the center of the wing and curves toward the apex. In Menecles and the other Pentatomini its basal part is not traceable. The posterior furrow, between corium and clavus, is bordered in front by media and behind by cubitus. The veins of the membrane are not shown in the drawings. They seem to be derived mostly from media and the radial sector.

In the fore wing of Tessaratoma (Pl. XVI, Fig. 2) the venation is traceable throughout, and is evidently more primitive than in Menecles. It may appropriately be compared with the coreid venation, as in Anasa (Fig. 3). In Anasa the veins may be traced by transmitted light, but in many coreids (Alydus, Harmostes, etc.), they are marked by distinct raised lines. The principal difference between the two is in the remarkable length of the radiomedial cross-vein in the pentatomid. There is a suggestion of this cross-vein in the tracheal branching of media in Comstock and Needham's Figure 21 *(loc. cit.)*.

The cydnine fore wing is quite like that of the pentatomids in venation of the corium. The veins of the membrane, which are nearly longitudinal in the Pentatomidae, here appear to radiate from its inner angle. The line between corium and membrane is squarely transverse.

In Scutellerinae and Thyreocorinae the fore wings show a remarkable modification related to the enlargement of the scutellum. The triangular area of the corium between the two furrows is invaded by

* Am. Nat., Vol. 32, p. 250.

membrane, which, however, does not reach the base of the triangle. The remaining chitinous area is sharply limited in front of this membrane, apparently by a vein, which is perhaps media much displaced, although in some cases the remnants of media seem still present on the anterior side of the claval furrow, the narrow clavus remaining chitinized for a large part of its length, bounding the membranous area posteriorly. The Graphosomatinae, also with an expanded scutellum, have the corium similarly reduced, but the claval region is also membranous except at base, the chitinous portions being delimited by a very oblique, nearly straight, line.

The hind-wing venation is more generalized and of considerable systematic importance. The folds are easily confused with the veins, but are recognized as being most distinct at the outer margin, where they end at the retreating angles between the more or less scalloped lobes. The first furrow, that behind media, corresponds to the posterior one of the fore wing.

By far the most primitive hind wing I have seen in the Pentatomidae is that of one of the Coptosomidae (Brachyplatys? sp.) from Manila. The stems of subcosta, radius, and media are all complete and apparently simple. In the next lobe, between folds, the two short veins—which in Pentatomidae are often connected basally near the middle of the wing but have no common stem on the basal half of the wing, or at best only a doubtful one—seem to be the posterior branch of media and the anterior branch of cubitus respectively, cut off by the folding of the wing. Behind this are two more very distinct lobes: the first contains cubitus and the first anal; the next and last, the second anal. The strongly lobed wing-outline closely resembles that of Thyreocorinae, but there is no trace on cubitus of the stridulatory organ found in all Cydnidae examined (Pl. XVI, Fig. 6, 8). Radius and media are fairly straight, and are connected by a long discal cross-vein.

In the Scutellerinae (*Homaemus proteus,* Pl. XVI, Fig 5) the following modification appears, which I have found in all related Heteroptera: radius sags down at the cross-vein to meet media, and media has an upward sinus, thus shortening, nearly obliterating, the cross-vein. In other forms the two stems are usually fused for a short distance. The basal part of radius as far as the beginning of the sinus, closely parallel to subcosta, is very faintly or not at all traceable; but the decurved part persists as a strong curved spur, the hamus, free at its basal end. The second vein in the middle fold is apparently wanting. The wing is evidently related to that of the Coptosomidae.

In Coreidae (*Anasa tristis,* Pl. XVI, Fig. 10) radius is feebly indicated basally, and discally is fused for a short distance with media. An evident hamus is present. Otherwise the venation is essentially as in Pentatomidae.

In the Thyreocorinae (Pl. XVI, Fig 11), in the Halydinae, in Tessaratoma (Fig. 7), and probably also in Cyrtocorinae, radius seemingly is present, slightly diverging from subcosta. But the clear-cut hamus

in the strongly marked venation of Sehirus (Fig. 6), Brochymena, and Tessaratoma, I believe to be the middle part of radius as in Homaemus, and the stem to be that of media and not radius. It remains to account for the vein extending basad along the first furrow from the apical part of media. It seems explainable only as a false vein, developed to strengthen the wing, analogous to the veinlike extension of the angulation of media in Sarcophaga.

In the Pentatominae (Pl. XVI, Fig. 9), Asopinae (Fig. 4), Graphosomatinae, and some Tessaratominae (Piezosternum) the stem of media seems to be complete from base to its union with the radial sector, closely contiguous to subcosta throughout, without trace of any hamus. Without the series at hand showing the gradual substitution of the medial stem in place of that of radius, this vein would be accepted without question as radius, and a divergence in evolution would consequently be assumed; on the one hand radius dominant, on the other, media. The two veins in the middle lobe converge strongly at base and meet in a curve.

An interesting structure in Corimelaena (Thyreocorinae) is a strongly chitinized sub-basal portion of the first anal vein. This portion is turned slightly so as to be nearly parallel to the long axis of the wing, and has a fine and beautifully regular cross-striation. It is evidently a stridulatory organ.

THE NYMPHS

The genera are usually easily recognizable among nymphs; but in some genera at least the separation of species is more difficult than with the adults. The notal color-pattern is useful, for although it is quite variable in extent and shade the fundamental plan does not change. The identity of a species is, of course, best determined by rearing, but can often be safely deduced by careful comparison with the adult, with especial regard to the head and anterior region. The spines and angles of the adult are seldom similarly present in the nymphs; the wings and scutellar structures are undeveloped; but the tergum, of which we see too little in the adult, is revealed with its important and interesting structures. The pleural osteoles of the adult are wanting in the nymph, their function being performed by the tergal scent-glands. The abdominal margin bears on each segment a circular or elliptical differentiated thicker area, lapped over the edge, half of it above and half below. These I call simply lateral plates, usually referring to the dorsal part. Along the middle of the abdomen above and below are similar areas, the median plates, the dorsal ones containing the scent-glands. All these plates are variable in color, but constant in extent in each stage, being proportionately larger in the very young nymphs.

The first scent-gland is on the hind margin of the third dorsal segment. It is unlike the others *, more simple, and for aught I know may not usually be functional. There is a long transverse "slit," or impressed suture, derived from the suture between the third and fourth segments,

* In an undetermined pentatomid nymph from Manila this difference is remarkably slight.

ending each side in an oval wrinkled area. The second and third glands, closely resembling each other, follow on the next two segments, and there is a similar transverse slit, more distinct however, ending each side in a hook-shaped groove with raised inner margin. There is often a trace of a fourth gland on the suture between the sixth and seventh segments. There are at least three mediodorasl plates, one for each gland, often a small fourth one, and sometimes more, as in Cydnidae. The plates are sometimes divided medially or are partly confluent (Corimelaena).

Behind each abdominal spiracle except the first are usually a pair of large setigerous punctures, the spiracular punctures, which are longitudinally placed in the Thyreocorinae, and included with the spiracle in the lateral plate. In the other subfamilies studied they are outside the lateral plate, placed transversely, except that in Cydnini they become oblique on segments 3–6 from the shifting of the inner one, and in Perillus from the crowding of the outer one by the lateral plate.

The genital structures are scarcely differentiated enough in the nymphs for use in classification. The male may be distinguished by the swollen penultimate ventral, which is often longer at middle than near the ends; sometimes there is a triangular depression on the hind margin at middle, notching the swollen portion. In the female this segment is not swollen, nor longer on the median line, and the entire median part is usually separated off to form a small depressed and flattened plate.

In the first and second instars the mesonotum is of nearly equal width throughout; the metanotum is similar, reaching the lateral margin and more or less convexly curved behind. In the third instar the metanotum is still curved behind and laterally tapers to a point near the margin; in the fourth it is nearly straight behind or, in Scutellerinae, a little convex at middle, and is overlapped now at each end by the anterior wing-pads, which attain its hind margin. In the fifth and last instar both wing pads project backwards well beyond the middle part of the metanotum, and the scutellum usually attains its hind margin at middle in Pentatomidae, but hardly in Cydnidae. The characterizations in the nymphal keys apply especially to the last instar, but are constructed so that they will usually answer for the fourth, and often for the third also.

Superfamily *PENTATOMOIDEA*

The group covered in this paper is the superfamily Pentatomoidea of Uhler's check-list and Kirkaldy's Catalogue, and the family Pentatomidae of Lethierry and Severin's Catalogue and of Van Duzee's Annotated List and his Catalogue. It is a well-marked group, recognized by the five-segmented antennae, the broad form, and the size of the scutellum, which is always at least moderately large, and often greatly expanded so as to cover nearly the entire dorsum behind the pronotum, as well as all of the elytra except the costal border. The present group includes three families. One of them, Urolabididae, is confined to Asia, Australia, and neighboring islands. The other two may be separated as follows.

Key to Families

NYMPHS

Hind tibiae nearly glabrous or with soft pale hairs, sometimes with short black spinulose hairs as in Euschistus; plantar surface of first tarsal segment rather densely hairy except on basal middle; dorsal abdominal sutures considerably distorted by scent-glands, terminal hooks of glands usually well marked; two spiracular setae transversely placed (rarely obliquely), behind the spiracle... .....Pentatomidae.

Hind tibiae with distinct and rather long spinules, and some inconspicuous hairs; plantar surface of first tarsal segment smooth and shining, with a few sparse hairs (Cydninae) or a row each side (Thyreocorinae); dorsal abdominal sutures easily traced, not greatly distorted, terminal hooks of glands but little developed; slit on anterior scent-gland not longer than slits of the succeeding glands .....Cydnidae.

IMAGINES

Tibiae not distinctly spinose, [if with short setulae the dorsal surface is longitudinally concave and has a slender ridge on each side;] more than five dorsal segments in addition to the genital series; caecal pockets, when present, in four rows, cubitus of hind wing not modified.....Pentatomidae.

Tibiae evidently spinose, [the dorsal surface rounded or angular, not concave;] only five dorsals in addition to the genital segments; caecal pockets in two rows; cubitus of hind wing bent and finely transversely ridged near base..... .....Cydnidae.

Family PENTATOMIDAE

Key to Subfamilies

NYMPHS

Anterior scent-gland with slit evidently longer than those of the succeeding glands, the terminal pores apparently functional.....Scutellerinae.

Anterior scent-gland feebly developed, as long as the next or slightly shorter; in Murgantia somewhat longer, since the next is unusually short.

Jugal margin in front of eye with evident spine; prothoracic margin with conspicuous large subspinose teeth perpendicular to the margin (Brochymena) .....Halydinae.

Jugal margin in front of eye with rounded tooth or unarmed; prothoracic margin finely serrate or entire.

Rostrum slender beyond the basal part of first segment; second segment more than twice as long as its narrowest part, seen from below..... .....Pentatominae.

Rostrum as seen from below very thick, of nearly equal breadth throughout; second segment about twice as long as broad.....Asopinae.

IMAGINES

Scutellum U-shaped, very large, nearly or quite reaching tip of abdomen; frena wanting or extremely short, less than 1/5 length of scutellum; opaque part of corium greatly narrowed.

Stems of media and subcosta in hind wings more or less divergent basally and remote; base of radial sector persistent as a distinct free recurved spur (hamus).

Tarsi 3-segmented; frena wanting; stem of media widely separated throughout from that of subcosta; apical part of media rarely with veinlike extension from the angle toward base of wing.....SCUTELLERINAE.

Tarsi 2-segmented; frena very short; stem of media nearing that of subcosta beyond middle (Calif., Trop. Am.).....CYRTOCORINAE.

Stems of media and subcosta subparallel, approximate; hamus wanting; no indication of frena; opaque part of corium narrow, triangular, the apical margin very oblique.....GRAPHOSOMATINAE.

Scutellum subtriangular, rarely approaching tip of abdomen or somewhat U-shaped; frena at least 1/4 as long as scutellum; opaque part of corium broad and subtriangular.

Juga laterally toothed near apex *; basal part of stems of media and subcosta slightly divergent and separated, hamus distinct but short.....HALYDINAE.

Juga not laterally toothed.

Spiracle of first visible ventral (really the second) exposed, a short but evident distance away from the metasternal margin; bucculae subparallel or slightly converging behind, first rostral contained in the groove or partly free and projecting at an angle; stem of media either contiguous to subcosta without trace of hamus, or divergent and somewhat distant from it with well-developed hamus (Mex. to S. Am., Cuba, Asia, Africa, Australia).....TESSARATOMINAE.

Spiracle of first visible ventral covered, rarely exposed just at the metasternal margin; stems of media and subcosta contiguous and parallel, with very little or no trace of hamus.

Bucculae subparallel, not united posteriorly, the first rostral not free, occupying the groove between them, at least in its posterior part.

[Thorax with a longitudinal central ridge on ventral surface between the coxae on entire length; abdomen almost keeled ventrally on its entire length, with a long sharp curved process projecting forward between hind coxae; prothorax produced on venter anteriorly in form of a plate as in Scutellerinae, the inner margins of plates reflexed, forming a ridge on each side of median line; tarsi 2-jointed.....ACANTHOSOMINAE.]

[Thorax and abdomen normal, without ventral keel or ridge; or if keeled the tarsi are 3-jointed; prothorax produced anteriorly as above in Neottiglossa and Aelia only; caecal pockets present; tarsi 3-jointed .....PENTATOMINAE.]

Bucculae convergent and united behind, the first rostral thick, free, directed away from the head, only its base being between the bucculae; caecal pockets absent.....ASOPINAE.

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* This should not be confused with the tooth of the side of the head at the base of the antennae.

Subfamily *SCUTELLERINAE*

The species of this family exhibit a considerable variation in color-pattern and ground-color, and care must be exercised to draw the specific lines correctly.

[In examining both nymphs and imagines in our collection I have been struck by the fact that the Scutellerinae have the prothorax produced anteriorly on each side on venter in the form of a sharp plate which assumes different outlines in different species, but in all of them the plate of each side is curved caudad just mesad of the outer margin of the fore coxa and forms a ridge on each side of the medial line; in the groove thus formed the rostrum lies in similar manner as in that on venter of head. In none of the other subfamilies except Acanthosominae is there invariably such plate-like anterior extension of the prothorax, the only other exceptions known to me being Trichopepla and Aelia. I have refrained from introducing the character in the subfamily key as I am not sufficiently familiar with the Pentatomidae to judge as to the importance of this character. It is pertinent however to mention that the prothorax in most of the Cydnidae has the same characteristic central ridges anteriorly as in Scutellerinae.]

Key to Tribes

NYMPHS

Mediodorsal plate of anterior scent-gland nearly straight, narrow, slightly broader at each end to contain the terminal pore, but not extended back at the sides of the scent-gland, the pores of the two glands dissimilar (Eurygaster) ..... Odontotarsini.

Mediodorsal plate of anterior scent-gland very narrow in front of the next plate, greatly expanded backward on each side of it, so that the terminal pores of the first gland are laterad of those of the second, all being similar in appearance and similarly prominent (Homaemus) ..... Tetyrini.

IMAGINES

Venter without stridulatory areas ..... Odontotarsini.

Venter with median transverse pair of lustrous finely striated stridulatory areas, borne on at least the 4th and 5th ventrals ..... Tetyrini.

Tribe ODONTOTARSINI

Key to Genera *

Osteole distinct, continued in a narrow canal; connexivum rather broadly exposed ..... 1. *Eurygaster*.

Osteole indistinct, without evident canal.

Head gradually narrowed to tip, not truncate anteriorly; body silky-pubescent (Col.) ..... *Fokkeria* Schout.

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* In this key and in those which follow, numbers before generic names indicate genera which are treated in the text.

Head in front broad and subtruncate.
Sides of pronotum sinuate, lateral angles notched.
Surface nearly smooth, pronotal collar slightly arcuate.....2. *Phimodera.*
Surface above corrugated, pronotal collar elevated hoodlike over base of head (Col.) .....*Euptychodera* Bergr.
Sides of pronotum feebly arcuate, lateral angles entire (Cal., Colo., Nev., Wyo.) .....*Vanduzeeina* Schout.

1. Eurygaster Lap.

Eurygaster alternatus Say

Tetyra alternata Say, Am. Ent., Vol. 3, 1828; Compl. Writ. on Ent. N. A., Vol. 1, p. 94.

Taken by the author in the grassy bog at Sun Lake, Lake Co., Ill., August 3 and 9. Other specimens are labeled "N. Ill." We have it also from Minnesota, July 10 (Zetek). Can., U. S. from Me. to Cal., south to N. M. (V. D.).

2. Phimodera Germ.

Phimodera binotata Say *

Scutellera binotata Say, Narr. [Keating's] of Exped. [Long's] to Source of St. Peter's Riv., etc., 1823, Vol. 2, App., p. 39. 1825. Also Say's Compl. Writ. Ent. N. A., Vol. 1, p. 198.

Two examples, taken by the author in the Illinois valley sand-region near Havana May 31 and October 29; eleven specimens, Havana, April 6, 1917 (C. A. Hart, J. R. Malloch).

Tribe TETYRINI

Key to Genera

Osteolar opening nearer to hind coxa than to side margin.
Osteole continued in a distinct canal.
Costal border of elytra exposed not farther than middle of scutellum; canal long.
Canal slender, slightly widened apically and curved forwards.....1. *Homaemus.*
Canal greatly expanded apically into a punctate area and bent angularly forward [ventral prothoracic plate as in Pl. XVII, Fig. 18]—Fla., Tex., N. M. (Bol.), Ariz., Trop. Am.....*Sphyrocoris* Mayr.
Costal border of elytra exposed beyond middle of scutellum.
Sulcus on dorsal face of tibiae divided lengthwise into two sulci by a slight ridge, at least basally.....2. *Stethaulax.*
Sulcus on dorsal face of tibiae simple (Fla., Trop. Am.)....3. *Symphylus*
Osteole not continued in a distinct canal.
Pronotum without transverse impression near middle—S. C. and Fla. to Tex. (V. D.).....*Diolcus* Mayr.

[* Mr. Hart was not sure of the identification of this species, but material collected in 1917 leaves no doubt in my mind as to the correctness of the identification.]

Pronotum with distinct transverse impression near middle; small black species.

Sides of pronotum and head entire—Fla., Tex., Ariz., Cal., Vancouver (V. D.) ..... *Camirus* Stål.

Sides of pronotum and head denticulate..... 4. *Acantholoma.*

Osteolar opening nearer to side margin than to hind coxa, without canal.

Costal border of elytra exposed beyond middle of scutellum.

Connexivum distinctly exposed in part (N. Y., Md., D. C., Fla., Tex., Ariz., Trop. Am.) ..... *Tetyra* Fabr.

Connexivum very nearly or quite covered by scutellum (Cal.?, Mex. to S. Am.) ..... *Pachycoris* Burm.

Costal border of elytra covered by scutellum except basally (S. C., Ga., Fla., Trop. Am.) ..... *Chelysoma* Bergr.

1. Homaemus Dall.

In our series I have been unable to verify satisfactorily the minute structural specific differences given by Van Duzee, and my previously published key * depends too much on the form of the color-pattern.

[The shape of the anterior platelike extension of prothorax on venter is very characteristic, and as it is useful in separating the southwestern species *proteus* from the other three I have figured it (Pl. XVII, Fig. 12–15) for all four species.]

Key to Species

NYMPHS

Pronotal lateral margin minutely serrulate, almost entire; an impunctate white callus in front of the terminal pore of each scent-gland.

Lateral plates black on inner half, pale outwardly; callus large and conspicuous; hair sparse, a brassy luster..... *aenifrons.*

Lateral plates with black line on inner margin, and black dot in outer half; callus reduced, not very conspicuous in the general lighter brown of the dark areas; hair dense and fairly straight; little or no brassy luster..... ..... *parvulus.*

Pronotal lateral margin rather coarsely acutely denticulate; no white callus; hair dense, curled; lateral plates with a black line on inner margin and a black spot occupying half or a third of the outer margin [Tex., Mex.].. *proteus.*

IMAGINES

Head above bronzy black, sparsely short pubescent, without yellowish border; costal border more or less barred with black; pattern obscure, more or less mottled; length, 7–9 mm..... *aenifrons.*

Head above black or bronzy black, with yellowish margin or submarginal line; costal border pale; general color pale yellowish, with pattern more or less distinct.

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* Bul. Ill. State Lab. Nat. Hist., Vol. 7, p. 264.

Larger species (6½–8 mm.); head bronzy black, with short sparse pubescence; sides of pronotum straight or slightly arcuate, apical expansion of pale median line of scutellum parallel-sided or narrowed anteriorly, bordered by black shading ..... *bijugis.*

Smaller species (4½–6½ mm.); head black, with rather dense longer whitish pubescence; sides of pronotum concave at middle, hind angles more acute; apical expansion of pale median line of scutellum bordered with a black line and broader anteriorly ..... *parvulus.*

HOMAEMUS AENIFRONS Say

Scutellera aenifrons Say, Narr. [Keating's] of Exped. [Long's] to Source of St. Peter's Riv., etc., 1823, Vol. 2, App., p. 40. 1825. Also Say's Compl. Writ. Ent., N. A., Vol. 1, p. 199.

From the Illinois valley sand-region near Havana and Forest City. Nymphs were taken June 6, and imagines June 27 and 29, August 15 and 20, and September 11 and 20. Also a single specimen from Rock Island in June. Parkdale, Minn., August 28 (Zetek). Taken in sweepings in grassy areas. Ranges across the continent from Canada south to Maryland and New Mexico.

HOMAEMUS BIJUGIS Uhl.

Homaemus bijugis Uhler, Prel. Rep. [1871] U. S. Geol. Surv. Montana, etc., p. 393. 1872.

One specimen from Union Grove, Ill., in the sandy region along the upper Mississippi, July 13, 6 specimens from Elizabeth, Ill., July 6, 7, 1917 (Hart and Malloch); Fergus Falls, Minn., July 10 and 17 (Zetek). Arid plains, Nevada and Colorado to Nebraska and Iowa (Van Duzee). The males are smaller than the females, and have more obscure markings.

HOMAEMUS PARVULUS Germ.

Pachycoris parvulus Germar, Zeit. f. Ent., Vol. 1, p. 107. 1839.

Tetyra grammica Auct., *nec* Wolff, Icones Cimicum, Fasc. 5, p. 172. 1811.

Taken in sweepings in southern Illinois at Odin, Dubois, Carbondale, Parker, and Cobden, May 8 to July 20; nymphs, May 30. Col. and Mex. east to N. C. and Fla. (V. D.).

[In addition to characters given in key, *parvulus* may be distinguished from *bijugis* by the longer fifth ventral abdominal segment, which is usually at least half as long as sixth, the presence of lateral black spots on venter, and the shape of the anterior prothoracic ventral extension.]

2. STETHAULAX Bergr.*

There is but one species of this genus recorded from North America.

STETHAULAX MARMORATUS Say

Tetyra marmorata Say, Descrip. n. sp. Heter. Hemip. N. A., 1831; Compl. Writ. Ent. N. A., Vol 1, p. 310.

[* This genus was taken in Illinois subsequent to Mr. Hart's death, and the treatment of it herein is by the editor.]

Aulacostethus simulans Uhler, Bul. U. S. Geol. and Geogr. Surv., Vol. 1, No. 5, sec. ser., p. 272. 1876.

The only Illinois specimen in our collection is a female taken at Cobden May 9, 1918, by the writer. The species has been recorded by Van Duzee from N. Y., Md., N. J., N. C., Ga., Tex., and Cal. In the Bolter Collection there are specimens from Arizona.

I can not detect the central ridge on hind tibia in this species even at base, and in this respect it very closely resembles specimens from Florida in the Bolter Collection labeled Symphylus, and recorded in the next paragraph. I have figured the dorsal aspect of head (Pl. XVII, Fig. 16), osteolar opening (Fig 21), anterior outline of ventral lateral portion of prothorax (Fig. 19) and genital segments (Fig. 24) of *Stethaulax marmoratus* and this Symphylus species (figures cited in next paragraph) to illustrate the distinctions between them. These Florida specimens undoubtedly represent a species not included in our North American list.

3. Symphylus Dall.

This genus is now included for the first time among the Nearctic genera by reason of several examples of a species in the Bolter Collection labeled Symphylus, from Indian River and Point Orange, Florida. [(Pl. XVII, Fig. 17, 20, 22, 23; cf. with figures cited in previous paragraph.)]

4. Acantholoma Stål

Acantholoma denticulata Stål

Acantholoma denticulata Stål, Enum. Hemip., Pt. 1, p. 17. 1870.

Four specimens in Bolter Collection and one in Natural History Survey collection, all labeled "N. Ill."; one specimen, Dubois (S. Ill.), August 8, 1917 (J. R. Malloch); Kan. (Kirkaldy); Ind., Ill., Kan. (V. D.).

Subfamily *GRAPHOSOMATINAE*

Key to Genera

Side margin of pronotum at anterior angle bearing a tooth.
- No metasternal carina ..... *Amaurochrous.*
- A sulcate metasternal carina (Col.) ..... *Weda* Schout.

Side margin of pronotum at anterior angle bearing a subquadrate lobe, the apical margin denticulate (Va., Tex., Vancouver) ..... *Oncozygia* Stål.

Amaurochrous Stål (Podops Lap.)

Smaller species, male 4½–6 mm., female 6–7 mm.
- Anterior pronotal tooth narrow, apical angle about 45°, sides of pronotum with slight sinus near middle, otherwise nearly straight from anterior tooth to apex of posterior tooth, which has an apical angle of about 60° .... *parvulus.*
- Anterior pronotal tooth broader, apical angle 60°–90°, sides of pronotum markedly sinuate, nearly transverse behind the sinus, suddenly rounded into an obtuse lobe on the posterior tooth, so that its apical angle is about a right angle ..... *cinctipes.*

Larger species, male 7 mm., female 7–9 mm., pronotum about as in preceding species ..... *dubius.*

Amaurochrous parvulus V. D.

Podops parvulus Van Duzee, Trans. Am. Ent. Soc., Vol. 30, p. 22. 1904.

Taken at Normal in central Illinois, March 26 and June 27; also in northern Illinois. Can., Mass., Kan., Col. (V. D.).

Amaurochrous cinctipes Say

Tetyra cinctipes Say, Am. Ent., Vol. 3, 1828; Compl. Writ. Ent. N. A., Vol. 1, p. 94.

Seems to prefer sandy land, and often occurs in driftwood collections. The imagines are found in all sections of Illinois, and throughout the year except in April and the early part of May. Algonquin, Urbana, Homer, Monticello, Havana, Quincy, Carbondale, and Pulaski, March 19, 30; May 19, 24, 28, 31; June 9, 21; July 9; August 16, 19, 20; September 21; October 27, 28, 30; Nov. 14. Occurs in some of the Southern States, but is more especially a species of the northern states and Canada. N. Y., N. J., Can. (V. D.). Duluth, Minn. (Bol.).

Amaurochrous dubius P. B.

Scutellera dubia Palisot de Beauvois, Ins. rec. en Afr. et en Amér., p. 33. 1805.

This species occurs in the West Indies, and has been reported from N. Y., N. J., Va., and Tex. The Bolter Collection contains a female 8 mm. long, apparently of this species, from Nantucket Island, Mass. [The species may occur in Illinois.]

Subfamily *HALYDINAE*

Includes but one genus in Illinois.

Brochymena A. & S.

Key to Species

NYMPHS

Pronotum with large, irregular lateral thorns, the lateral outline not straight, very conspicuously angularly produced on posterior third, lateral cephalic margin with a short thorn just in front of eye ..... *arborea.*

Pronotum with small, almost equal-sized lateral teeth, the lateral outline almost straight, only slightly produced near posterior extremity; lateral cephalic margin with a short triangular protuberance just in front of eye... *4-pustulata.*

IMAGINES

Osteole very small and inconspicuous, the auricle pale and very small or almost absent; pronotum produced in the form of a broad truncate process at lateral posterior angles, its apex with 2 or 3 sharp teeth; the paired plates at base of genital segments of female bulbous, their posterior margins declivitous..... ..... *arborea.*

Osteole large, the auricle dark and well-developed; pronotum either broadly rounded at posterior lateral angles or rather sharply angulated, usually with small denticles; the paired plates at base of genital segments of female slightly convex or flat, their posterior margins not declivitous.

Osteole not surrounded laterally by pale yellowish color; apical dorsal segment of female conspicuously emarginate posteriorly; large species, females averaging 18 mm. in length; color of dorsum as in the other species of the genus but there is a paler area at apex of scutellum and on base of each elytron that is not so evident in any other species before me; lateral margin of metathorax narrowly pale yellow from base to apex.....*cariosa.*

Osteole surrounded laterally by pale yellowish color; apical dorsal segment of abdomen of female transverse or slightly emarginate; lateral margins of metathorax not narrowly pale.....*4-pustulata.*

[The above keys and the record of *B. cariosa* in text are by the editor. Mr. Hart's key to imagines included only *arborea* and *4-pustulata* which were separated on entirely different characters.]

Brochymena arborea Say

Pentatoma arborea Say, Jour. Acad. Nat. Sci. Phil., Vol. 4, p. 311. 1825.

This also is a widely distributed species, ranging from Canada into Mexico, and over nearly the whole of the United States. Its habits are very similar to those of the preceding species, but it seems to be most abundant later in the season. Examples determined by H. E. Summers were reported to us as spearing on their beaks larvae of the Colorado potato-beetle. Beach, Urbana, Twin Grove; Centralia, Dubois, Metropolis; March 18, May 9, June 10, July 3 (on apple), August 19, September 6–14 (on apple), 20, 22, November 7. G. H. French reported to us that he found Brochymena in all stages on willow, apple, and grape, and also took adults on peach and pear, his localities being Centralia, Carbondale, Makanda, Cobden, and Villa Ridge, and the dates August 26, 28, and September 5, 12, 26.

Brochymena cariosa Stål

Brochymena cariosa Stål, Enum. Hemip., Pt. 2, p. 17. 1872.

One female which I found in the series of *4-pustulata* is undoubtedly *cariosa,* agreeing in every respect with Texan examples so named by Mr. Hart.

Locality, Whitesville, Saline Co., Ill., June 29, 1905.

Brochymena quadripustulata Fabr.

Cimex quadripustulata Fabricius, Ent. Syst., sec. ed., Vol. 4, p. 100. 1794.

This is our commonest species. It ranges from the eastern United States to California and is also found in Canada. It occurs in all sections of Illinois, but is perhaps commonest in the southern part. It rests on the branches of trees, protected by its color. We have found it on elm and grape, but it has been noted especially in orchards, on apple and cherry trees. Sanderson has recorded it as preying on the tussock and brown-tail moths; but its abundance in all stages on trees suggests that

it may also feed on the sap. We have never seen any with their beaks inserted, but H. Garman, while an assistant at the State Entomologist's office, found them very abundant on apple trees injured by twig punctures. We have taken them hibernating in December; they occur abundantly on apple, oak, elm, and other trees in May and June; and the nymphs in our collection were taken in late June, July, and August. The adults on apple trees, mentioned above, are perhaps the hibernating generation, the next generation being that taken by us in August, September, and October. Localities are as follows: Milan and Andalusia in Rock Island county; Urbana, Peoria, Havana, Griggsville, and Pegrim; Collinsville, Olney, Clay City, Flora, Odin, Centralia, Richview, Dubois, Du Quoin, Mt. Vernon, Carbondale, Grand Tower, Cobden, Anna, Pulaski, and Villa Ridge, in southern Illinois, the dates being April 7, 17, 19, 20; May 15, 18, 19, 21, 23, 24, 26, 27, 30; June 1, 4, 6, 8, 10, 13, 21, 26, 29; July 8, 17, 25; August 13, 14; September 2, 11, 14, and 20; and October 15, 31. Eggs of Brochymena, probably of this species, or of *arborea,* we have collected in late June, and from these we bred two parasites, determined for us by the U. S. Bureau of Entomology as Anastatus sp. and *Trissolcus murgantiae* Ashm.

Subfamily *PENTATOMINAE*

Key to Tribes

NYMPHS

Juga broad, surpassing tylus and in close contact beyond it for a distance about equal to the width of a jugum.....EDESSINI.

Juga slender, straight, subacute, surpassing tylus by at least the width of a jugum, nearly or quite in contact beyond it; body elongate.....MECIDIINI.

Juga sometimes surpassing tylus, but by much less than a jugal width, and not in contact beyond it.....PENTATOMINI.

IMAGINES

First rostral not evident between the bucculae anteriorly, apparently emerging behind the middle of the head, attaining the fore coxae.....DISCOCEPHALINI.

First rostral resting about parallel to the under surface of head, its basal end evidently in front of middle of head.

Body regularly ovate, broadest behind middle, margins all explanate; sides of tergum rather broadly exposed.....SCIOCORINI.

Body usually broadest at lateral angles of pronotum, margins not uniformly explanate; sides of tergum narrowly or not at all exposed.

Metasternum with a median smooth elevated area, strongly notched behind to receive the ventral spine, and prolonged forward as a bifid process; juga usually meeting broadly in front of tylus (Trop. Am., Fla. to La.)... .....EDESSINI.

Metasternum with not more than a simple median carina.

Venter with first three segments each side of middle bearing a curved stridulatory band, finely and densely cross-striate; body elongate, about four times as long as its greatest breadth (Mecidea).....MECIDIINI.

Venter without finely striated stridulatory band each side near base; body not over three times as long as its greatest breadth.....PENTATOMINI.

Tribe DISCOCEPHALINI

KEY TO GENERA

Head narrower than apical margin of pronotum; side of head with spinose prolongation in front of eyes.....1. DRYPTOCEPHALA.

Head as broad as apical margin of pronotum; side of head without spinose prolongation in front of eyes.....2. PLATYCARENUS.

1. DRYPTOCEPHALA Lap.

This genus I have added to the list of our fauna because of a nymph showing its peculiar head-structure, taken at Brownsville, Tex., November 21. I have nymphs apparently of the same species from Valles, Mex., near Tampico.

2. PLATYCARENUS Fieb.

Two species of this genus are listed under Discocephala from Texas and Arizona respectively by Banks.* They belong to the subgenus Platycarenus, which Kirkaldy lists as a genus.

Tribe SCIOCORINI

SCIOCORIS Fall.

SCIOCORIS MICROPHTHALMUS Flor

Sciocoris microphthalmus Flor, Rhynch. Livl. etc., Vol. 1, p. 114. 1860.

This European species was taken on the White Mountains by Mrs. Slosson. In the Bolter Collection are two examples: one from Duluth, Minn.; the other from the Lake Superior region. The species is labeled *umbrinus,* but seems quite certainly *microphthalmus.*

Tribe EDESSINI

The large neotropical genus Edessa is represented in our fauna; Florida to Louisiana.

Tribe MECIDIINI

It seems possible that this tribe, based by Bergroth on the presence of stridulatory areas, may prove not to be a natural group.

MECIDEA LONGULA Stål

Mecidea longula Stål, Of. Kongl. Vet.-Akad. Förh., Vol. 11, p. 233. 1854.

This interesting, very elongate pentatomid is known from Texas, New Mexico, Colorado, and Iowa, and its occurrence in the sand areas of western Illinois is a possibility.

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* Cat. Nearctic Hemp.–Het., p. 92.

Tribe PENTATOMINI

Key to Genera

NYMPHS

Hind tibiae glabrous or with soft pale hairs, without short black spinulose hairs or dark points bearing them; third mediodorsal plate (except in Mormidea) punctate behind slit of scent-gland, with distinctly impressed punctures.

Third mediodorsal plate punctate behind slit of scent-gland.

First scent-gland not longer transversely than the others.

Tergum, except the chitinous plates, impunctate.

Pleura impunctate, sometimes slightly rugose; part of third median plate behind slit large (as in Apateticus).

Notum with broad orange border, sometimes reduced or interrupted at hind pronotal angles; disc next to the border black, central portion, especially on scutellum, broadly or narrowly pale; lateral plates usually black; tergal sutures, true and false, often marked with darker lines ..... *Acrosternum.*

Notum greenish, narrowly bordered with black; pronotal border within the black line feebly orange; disc of notum with pattern of distant black spots; lateral plates large, reaching sutures, pale rose-color ..... *Nezara.*

Pleura punctulate; part of third median plate behind slit short longitudinally.

Notum and tergum without evident pale border; lateral plates oblong, pale, with black inner marginal line; notum with vague black shades, a distinct smooth pale spot at lateral scutellar angles; tergal sutures usually darkened, as described for Acrosternum... *Thyanta.*

Notum and tergum with a uniform yellow or pinkish border, including lateral plates; abdominal sutures concolorous..... *Chlorochroa.*

Tergum evidently evenly punctate or punctulate, not merely mottled; smaller species.

Head glabrous or with a few sparse or very short hairs.

Juga considerably exceeding tylus.

Head flat, subtruncate in front, body subcircular; color brownish, a smooth pale notal border, except near hind pronotal angles; margin of head, inner margin of lateral plates, and borders of scent-gland slits narrowly black; punctures large, stellate..... ..... *Dendrocoris.*

Head convex, juga oblique in front; body oval or oblong; color pale, with four longitudinal black stripes, or else black, with median line of notum, a very narrow lateral margin, and intermediate spots, yellowish ..... *Neottiglossa.*

Juga slightly or not at all exceeding tylus; first median plate bearing a pair of distant oval black spots; outline subcircular; color yellowish, base and longitudinal sutures of head black, a discal pair of black spots on pronotum and another pair on scutellum; hind border of pronotum and much of wing pads black..... *Cosmopepla.*

Head with dense erect pubescence; tergum and venter (exclusive of plates) punctulate (not very densely) with dark punctures; body margin often more or less pale.

Juga exceeding tylus, and converging in front of it.....*Peribalus.*

Juga not exceeding tylus.....*Trichopepla.*

First scent-gland longer transversely than the others, which are small; plates all very large, punctate; tergum otherwise impunctate..*Murgantia.*

Third mediodorsal plate smooth, impunctate; pleura coarsely and deeply punctate, tergum and venter impunctate; notum black, its anterior and lateral border whitish yellow, also its median line, and an intermediate stripe running back on the tergum alongside of the scent-glands; tergal margin narrowly pale, disc rose-purple, inwardly subconcentrically streaked .....*Mormidea.*

Hind tibiae with dark points bearing minute black spinulose hairs; part of third median plate behind slit of scent-gland small and indistinct, often mottled, but without definite impressed punctures; pleurae impunctate or sparsely punctulate.

Pronotal lateral outline oblique, nearly straight or even concave, except near the hind angles, where it is prominent and strongly rounded;* abdomen impunctate.

Lateral plates oblong, pale, not mottled, bordered within by a nearly straight black line; notum with pale border, margined within by a black stripe; on the wing a discal second stripe; antennae black; pronotal lateral outline concave; mediodorsal plates except the last nearly or quite divided by a pale median stripe, leaving a pair of subquadrate black spots on the first plate, and a pair of elongate spots on the second and third plates .....*Solubea.*

Lateral plates semicircular, mottled, without black border, second and third mediodorsal plates each with a pale median line, each side of which is a rounded shining black prominence bearing a short pale oblique dash; antennae basally yellowish, annulate with white at second articulation, not merely narrowly pale yellowish at articulations as usual.....*Proxys.*

Lateral plates semicircular, more or less mottled, a black curve within or black dot at intersection of inner side with false suture; mediodorsal plates varying from mottled in older nymphs to solid black with median line and borders of slit pale; antennae partly pale except in very young nymphs .....*Euschistus.*

Pronotal lateral outline quite evenly arcuate, nearly continuous with the curve of the body outline, hind pronotal angles not at all prominent.

The pronotal lateral outline if continued forward would miss the eye by more than its diameter, the anterior angles in line with anterior eye-margins; tergum and venter distinctly and rather densely punctate; last antennal segment black; mediodorsal plates with dark spot at each end; ground-color fuscous .....*Menecles.*

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* This distinction is not evident in very young nymphs.

The pronotal lateral outline if continued forward would pass close to the eye, not less than its diameter from it, the anterior angles not as far forwards as anterior eye margin; ground-color pale yellowish.

Tergum and venter sparsely punctulate, second and third mediodorsal plates black, with median stripe and anterior edge of transverse slit pale; notum with blackish shades, but always a vague pale median stripe; antennae dark fuscous.....*Hymenarcys.*

Tergum and venter impunctate; second and third mediodorsal plates pale, with a pair of oblique black dashes in front of slit, and a pair of transverse ones on the posterior border; notum with only a short longitudinal black dash at base of each wing pad, and the usual sparse black punctures; antennae black.....*Coenus.*

IMAGINES

Juga straight, acute, surpassing tylus, but not converging in front of it.

Second ventral at middle produced forward in a stout spine between the hind coxae; mesosternum with very prominent median carina prolonged forwards (Cal., Ariz., Tex., Fla.).....*Arvelius* Spin.

Second ventral not produced in a spine.

Femora unarmed (Ariz.).....*Chlorocoris* Spin.

Femora acute at middle of apex above, ending in a minute spine....1. *Loxa.*

Juga obtuse, equaling tylus or converging and nearly or quite meeting in front of it; mesosternum without prominent carina prolonged forwards.

Second ventral at middle produced forwards in a stout spine or well-defined tubercle towards or between hind coxae. [See note at end of key.]

Juga not exceeding tylus.

Ventral spine passing middle coxae, spiracles large, black (Fla., N. Mex.) .....*Piezodorus* Fieb.

Ventral spine not reaching middle coxae.

First antennal surpassing head (Fla.).....*Vulsirea* Spin.

First antennal not surpassing head.

Second antennal more than half as long as fifth.

Osteolar prolongation acuminate, reaching over half-way to body margin.....2. *Acrosternum.*

Osteolar prolongation subtruncate, reaching less than 1/3 the distance to body margin (Coastal plain, Va.; Tex. (Hart).....*Nezara* A. & S.

Second antennal less than half as long as fifth; ventral spine sometimes reduced to a broad tubercle.....3. *Banasa.*

Juga surpassing tylus and nearly or quite meeting in front of it.

Osteolar sulcus drawn out laterally and tapering into a narrow ridge at apex.....4. *Dendrocoris.*

Osteolar sulcus short, truncated (Fla.).....*Brepholoxa* V. D.

Second ventral at middle sometimes convexly prominent, but not produced forwards in a stout spine or tubercle.

Osteole without a distinct anterior auricle, the margin of the orifice V-shaped at inner end, exteriorly drawn out into a tapering canal often shading apically into a narrow acuminate ridge arising from the posterior side of the canal.

Frena exceeding mid-scutellum; diffusion area well developed.
Osteolar prolongation short, reaching about 1/3 the distance from orifice to lateral margin of metasternum; juga not surpassing tylus..... .....(*Pentatoma* Auct.)
Sides of pronotum with distinctly reflexed margin.
Third rostral shorter than second and about equal to fourth..... .....5. *Chlorochroa.*
Third rostral about equaling second, and longer than fourth..... .....6. *Rhytidolomia.*
Sides of pronotum with margin acute but not reflexed (Atlantic states, Col., Mont., Lower Cal.).....*Liodermion* Kirk.
Osteolar prolongation reaching half-way or more to lateral margin of metasternum.
Juga not surpassing tylus.....7. *Thyanta.*
Juga surpassing tylus and meeting in front of it.....8. *Peribalus.*
Frena not reaching mid-scutellum; diffusion area very small and ill-defined .....9. *Trichopepla.*
Osteole with the rounded—rarely elongate—orifice on the outer side of a low elevation, which extends around its anterior side and outwardly, usually as a short raised auricle with a more or less free obtusely rounded apex.
Head at least 7.8 as wide as scutellum. [Prothorax with a sharp plate-like production of anterior margin on each side ventrally which curves ridgelike mesad of coxa but does not extend caudad beyond the latter.]
Pronotum with median ridge only; [lateral extension of prothorax on venter not extending beyond anterior margin of eye].10. *Neottiglossa.*
Pronotum 3-ridged, sides straighter; [lateral extension of prothorax on venter extending much beyond anterior margin of eye] (Col. and Neb., northward into Canada.....*Aelia* Fabr.
Head less than 7/8 as wide as scutellum.
Osteole with inner end nearly in line with outer sides of adjacent coxae, without evident raised auricle or canal or the usual large opaque area .....11. *Murgantia.*
Osteole about as far laterad of the outer sides of the coxae as the coxal diameter; an evident raised auricle and a well-defined large opaque area present, rarely one or the other not developed.
Hind tibiae smoothly rounded above, at least on basal half.
Bucculae strongly arcuate, much exceeded behind by first rostral.
Scutellar breadth at apices of frena fully twice length of frena.. .....12. *Cosmopepla.*
Scutellar breadth at apices of frena at most little more than length of frena.....13. *Mormidea.*
Bucculae nearly straight-edged, not exceeded behind by first rostral.
Tylus rounded at apex, not surpassing juga; eyes and pronotum contiguous .....14. *Solubea.*
Tylus acute at apex, strongly surpassing juga; eyes distant from pronotum about as far as their diameter.....15. *Proxys.*

Hind tibiae sulcate above, at least on basal half.
Pronotal hind angles emarginate (Iowa, Col. to Vancouver and Lower Cal., Me.) ..... 16. *Prionosoma.*
Pronotal hind angles not emarginate.
Bucculae sloping off at posterior end, without evident posterior lobe.
Margins of pronotum arcuate and explanate; membrane veins anastomosing ..... 17. *Menecles.*
Margins of pronotum sinuate; veins of membrane not anastomosing.
Frena reaching well beyond mid-scutellum.
Pronotal margin serrate anteriorly ..... 18. *Euschistus.*
Pronotal margin entire (Fla.) ..... *Padaeus* Stål.
Frena not reaching beyond mid-scutellum; pronotal margin entire (Kan. to Cal., north to Vancouver.. *Eysarcoris* Hahn.
Bucculae elevated at posterior end into a distinct lobe, ending abruptly behind.
Tylus not more prominent above than juga, which converge over it at apex (Col. to Cal., and N. Dak.) .... *Carpocoris* Kol.
Tylus throughout more prominent than juga, which are parallel.
Distal part of scutellum narrower than elytra .... 19. *Hymenarcys.*
Distal part of scutellum broader than elytra ..... 20. *Coenus.*

[It was the intention of the author to arrange his keys according to the natural sequence of the genera, but evidently the attaching of importance to certain characters led him to place between closely related genera one or more genera that are apparently not closely related to the genera which they separate. An example may be seen in the case of Dendrocoris, since the genera Thyanta and Banasa are undoubtedly very closely related while Dendrocoris, intervening, is readily separable from them by a number of striking anatomical characters which are in my opinion of paramount importance in this family. The male genitalia are very distinctive in all the species of Dendrocoris which I have seen, the deep central excavation and lateral clawlike processes (Pl. XVIII, Fig. 28) being strikingly different from the ordinary forms in Thyanta and its allies (Pl. XX, Fig. 70, 72, 75, 77). The genitalia of the females differ from those of Thyanta and allied genera in having the basal paired plates entirely covered by the apical ventral segment when in their normal position. In addition to the genital differences mentioned the metasternum of Dendrocoris lacks the central ridge except in some cases at its anterior extremity. The male of this genus frequently has no protuberance on the second abdominal sternite, but the above characters will identify such specimens.]

[The arrangement of the genera of Pentatominae and other subfamilies of Pentatomidae has apparently been rather arbitrary if one may judge from the repeated re-alignment of the constituent genera in various

publications, even those issued by the same writer, and it occurs to the editor of this paper that a careful study of all stages of the group would afford a fruitful field for some unbiased student.]

1. Loxa, A. & S.

Loxa sp.?

The Bolter Collection contains two examples of a species of Loxa labeled "N. Ill." The genus has hitherto been known only from N. Mex. and Tex. (Uhl.) and Fla. (Van Duzee).

2. Acrosternum Fieb.

Key to Species

Form short-oval, sides of pronotum conspicuously arcuated.....*pennsylvanicum.*
Form obovate, sides of pronotum nearly straight.....*hilare.*

Acrosternum pennsylvanicum De G.

Cimex pennsylvanicum De Geer, Mémoires pour Serv. à l'Hist. Ins., Vol. 3, p. 330. 1773.

Of this uncommon species we have several examples from northern Illinois in June. Its recorded range is from Massachusetts to Iowa and north into Canada. Banks has taken it on Ceanothus.

Acrosternum hilare Say

Pentatoma hilaris Say, N. Sp. N. Am. Ins. found by Joseph Barabino, chiefly in La., p. 9, 1832; Compl. Writ. Ent. N. A., Vol. 1, p. 304.

This very common large green species is in our collection from numerous localities in the various sections of the state. It ranges from Canada to Brazil, and from the Atlantic coast to the Pacific. The Bolter Collection contains specimens from California, from which it had not previously been reported. The life history is very evident from the data at hand. The imagines are most frequently taken in May and the early part of June; there are only a few dates in July and August, but they become more frequent in the latter part of September, with records for October and November. The nymphal records are all for July and August and the early part of September. A number of food plants, trees and herbs, are recorded. Our data show the occurrence of the nymph on grape and ash, and of the adult on catalpa and apple.

3. Banasa Stål

[There appears to be some uncertainty as to the identity of the species in this genus, and an examination of types appears to me necessary to definitely decide the matter. I have figured one side of the male hypopygium in *calva, dimidiata,* and *imbuta* Walker—a Texan species—(Pl. XVIII, Fig. 25, 26, 27), to facilitate identification of the species dealt with in this paper.]

Key to Species

Pronotum without any sharply contrasting color division.

General color dark chestnut or blackish; abdominal marginal incisures with evident black dot; basal angles of scutellum at most with very small smooth spots; [pronotum and basal half of elytra with narrow yellow lateral margins; male hypopygium similar to that of *calva*].....*sordida.*

General color greenish; abdominal marginal incisures without evident black dot; basal angles of scutellum with a smooth pale callus larger than eye; [pronotum and elytra without yellow lateral margins; male hypopygium similar to that of *dimidiata*].....*euchlora.*

Pronotum green or olivaceous in front of a line connecting the lateral angles; back of this line red-brown; the two colors in sharp contrast.

Abdominal marginal incisures with evident black dot; second antennal 2/3 to 3/4 as long as third; [male hypopygium as in Pl. XVIII, Fig 26]....*calva.*

Abdominal marginal incisures with not more than a minute black point; second antennal 1/2 to 2/3 as long as third; [male hypopygium as in Fig. 25] .....?.....*dimidiata.*

Banasa sordida Uhl.

Atomosira sordida Uhler, Proc. Boston Soc. Nat. Hist., Vol. 14, p. 98. 1871.

Two specimens taken by the author near the Mississippi River at Grand Tower, southern Illinois, June 30 and July 10. The species is recorded from Maine, Vancouver, and Arizona, and from some intermediate states.

Banasa euchlora Stål

Banasa euchlora Stål, Enum. Hemip., Pt. 2, p. 44. 1872.

This is a southern species, one ranging from Florida to Arizona (Bol.), and north to Maryland and Iowa. It was captured on cedar at Summerfield (S. Ill.) May 1, by E. S. G. Titus.

Banasa calva Say

Pentatoma calva Say, Descrip. n. sp. Heter. Hemip. N. A., 1831; Compl. Writ. Ent. N. A., Vol. 1, p. 318.

The species is known from Georgia, New York, and Montana. [We have one male from Grand Tower (S. Ill.) July 12, 1909.] Van Duzee says that near Buffalo (N. Y.) it is "tolerably abundant on various deciduous trees from August to October."

Banasa dimidiata Say

Pentatoma dimidiata Say, Descrip. n. sp. Heter. Hemip. N. A., 1831; Compl. Writ. Ent. N. A., Vol 1, p. 318.

This is our commonest species. It ranges from the Atlantic coast to California, and north into Canada. We have it from Algonquin and various other points in northern Illinois; also from Quincy (C. Ill.) May 12, September 9, and November 14, (and from White Heath (C. Ill.) November 22, 1913.]

4. Dendrocoris Bergr.*

There is but one species of this genus in our Illinois material, though we have apparently six species from the United States in the collection.

Dendrocoris humeralis Uhl.

Liotropis humeralis Uhler, Bul. U. S. Geol. and Geogr. Surv. Terr., Vol. 3, No. 2, p. 400. 1877.

This species is not uncommonly swept from black-jack oak at Havana, Forest City, and Meredosia. It also occurs under similar conditions at Alto Pass and Dubois. Other localities for Illinois are Galesburg, White Heath, Carbondale; and one specimen is labeled "N. Ill." Other states: Vt., Mass., N. J., Pa., Md., W. Va., Ga., Ohio, Iowa, Kan., Col., Cal.? (V. D).

Mr. Van Duzee places a question mark after the California record. Possibly the specimen or specimens referred to are identical with one in our collection from Yosemite Valley, Cal., which is closely related to *humeralis* though evidently specifically distinct.

The male hypopygia of the species before me are all of similar structure (Pl. XVIII, Fig 28), and differ strikingly from those of Thyanta. The female genitalia differ from those of Thyanta and allied genera in having the basal plates concealed beneath the preceding ventral segment.

Mr. W. L. McAtee informs me that he has taken some specimens of *humeralis* that differ from the normal form in having the juga separated at apices. These specimens were taken in the vicinity of Washington, D. C.

Mr. Van Duzee in his recent catalogue lists Dendrocoris near the end of its tribe, placing Arvelius before it and after Thyanta.

5. Chlorochroa

Chlorochroa uhleri Stål †

Chlorochroa uhleri Stål, Enum. Hemip., Pt. 2, p. 33. 1872.

Chlorochroa persimilis Horvath, Ann. Mus. Natl. Hung., Vol. 6, p. 555. 1908.

This species is exceedingly abundant in the Illinois valley sand-regions, swarming on *Opuntia rafinesquii,* and feeding mostly at the tip of the fruits when these are present. I have also taken it in the sand dunes of the Chicago area on dwarf cedar *(Juniperus sabina).* Vestal says that it also occurs on Chrysopsis, Kuhnia, *Ambrosia psilostachya, Lespedeza capitata,* and grasses. In the Illinois valley we have it from Forest City, Manito, Bishop, Havana, Bath, Arenzville, and Meredosia. In the Chicago area we have it from Beach and Waukegan; and there are also single examples from Eureka, near the Illinois valley sands, from Mascoutah, near St. Louis, and from Dubois. The dates are April 1, 4, 9; June 5, 6, 10; August 7, 12, 13, 14, 18, 22, 24; September 28, 30; Octo-

[* Treatment of this genus is by the editor.]

[† In Mr. Hart's MS. he uses the name *persimilis,* but Van Duzee's Catalogue gives this as a synonym of *uhleri,* in which he is followed here by the editor.]

ber 8, 15, 29, 30; and November 17. Nymphs occurred June 6 to October 30. In the late fall most adults are a dark brownish carmine resembling that of the ripe fruit of the Opuntia on which they occur. A few green individuals still remain, and it would seem that the red color is assumed at transformation, while mature adults are not affected. This dark variety was found abundant October 29, 30, and 31, and November 17. The species is common in sandy situations east to the Atlantic coast and in Iowa and Canada. It hibernates as an adult under shelter (Vestal).

[The claspers of the male hypopygia of *uhleri, sayi* Stål, *congrua* Uhler, and a species provisionally named *ligata* Say in our collection are very similar in structure, the most striking differences being found in those of the first two species as shown in Figures 29 and 30, Plate XVIII.]

6. Rhytidolomia Stål

Rhytidolomia belfragii Stål

Rhytidolomia belfragii Stål, Enum. Hemip., Pt. 2, p. 33. 1872.

Three specimens from northern Illinois in April (S. H. Peabody); Ill., Iowa, Neb., Canada (V. D.).

[Judging from the general habitus and hypopygial structure of this and the preceding species one might reasonably question the validity of the generic separation of the insects. The hypopygial claspers are very similar to those of Chlorochroa and are shown in Figure 31, Plate XVIII.]

7. Thyanta Stål *

Key to Species

Pronotal side margin anteriorly uneven and serrulate, usually a distinct black margin, a very distinct pair of black dots on pronotal disc, behind head; punctuation of disc of corium sparser than in the next species; male genital segment with median lobe rounded or subangulate.....*calceata.*

Pronotal side margin nearly entire, often dark-margined, disc without distinct pair of black dots; punctuation of disc of corium quite dense; male genital segment with median lobe nearly straight-edged.....*custator.*

Thyanta calceata Say

Pentatoma calceata Say, Descrip. n. sp. Heter. Hemip. N. A., 1831; Compl. Writ. Ent. N. A. Vol. 1, p. 320.

Mr. H. G. Barber has recently pointed out † the characters for the recognition of this species, which had been previously confused with *custator*. He states that *calceata* appears to be confined to the region east of the Alleghanies; but the species had already been recognized by Dr. S. A. Forbes as distinct in our collection. The localities are Urbana and Towanda (C. Ill.) and Tamaroa [and Alto Pass] (S. Ill.), and the dates are May 2, [8], and 18, and September 22. We have also specimens from Kentucky and Florida in the Bolter Collection.

* For synopsis of North American species see Addenda to this paper.
† Journ. N. Y. Ent. Soc., Vol. 19, p. 108.

Thyanta custator Fabr.

Cimex custator Fabricius, Syst. Rhyng., p. 164. 1803.

This common and variable species is easily recognized by its peculiar granulate appearance, caused by the fine and dense punctuation. There are two extreme color-varieties. One is green, often with a red band between the humeri and red lateral border to the pronotum; the other is brownish fuscous, more or less dotted above and below with fuscous, and with a pale median line on the scutellum. There are so many intergrades between these forms that a variety name is not considered necessary. The species is widely distributed over the United States. It feeds on asparagus, corn, and various grasses. Several examples of the dark variety were once captured by C. W. Woodworth on the top of a tower of the University of Illinois about 180 feet high. The species is moderately common in all parts of Illinois, especially on dry or sandy soils. The dates are distributed rather uniformly throughout the season. Collections in November and December indicate that hibernation in the adult stage is usual. Nymphs have been taken from May to July, but much more abundantly from August to October.

8. Peribalus Muls. & Rey

Key to Species

Under surface and legs piceous, connexival pale border more or less invaded by large square black spots at incisures; [posterior margin of hypopygial opening as in Figure 32, Plate XVIII] ..... *piceus.*

Under surface and legs pale, connexivum with narrow pale border, line between this and the black discal color more or less sinuated outwardly on the incisures; [posterior margin of male hypopygial opening as in Figure 33] .... *limbolarius.*

Peribalus piceus Dall.

Pentatoma? picea Dallas, List of Specimens of Hemip. Ins. in Coll. Brit. Mus., Pt. 1, p. 236. 1851.

We have numerous specimens from northern Illinois (S. H. Peabody). The species is rather rare, being listed from Canada, Montana, and Iowa.

Peribalus limbolarius Stål

Peribalus limbolarius Stål, Enum. Hemip., Pt. 2, p. 34. 1872.

This common species ranges across the United States and from Canada to Mexico. We have it from numerous localities in all sections of the state. It is particularly a late-summer and fall species. We have taken it in January, March, April, and May, but especially from June 19 to November 7, the largest number of captures being in October. The nymphs were taken during the summer months. It feeds on goldenrod (Kirkaldy). At Urbana, October 26, the author found twenty-three imagines on a single cauliflower stalk with their beaks inserted, evidently sucking the sap.

9. Trichopepla Stål

Key to Species

Sides of pronotum arcuate; head scarcely tapering; antennae black, first antennal rufous; basal half of scutellum finely and densely punctate.....*atricornis.*

Sides of pronotum nearly straight; head distinctly tapering, with three pale impunctate stripes; antennae black, basal two or three segments pale; basal half of scutellum coarsely and unevenly punctate.....*semivittata.*

Trichopepla atricornis Stål

Trichopepla atricornis Stål, Enum. Hemip., Pt. 2, p. 34. 1872.

Recorded from Illinois and Wisconsin, west to California and Alaska. Not represented in our collections.

Trichopepla semivittata Say

Pentatoma semivittata Say, Descrip. n. sp. Heterop. Hemip. N. A., 1831; Compl. Writ. Ent. N. A., Vol. 1, p. 319.

Ranges from Canada and Maryland west to Colorado. Our material shows a remarkable variation in size and color. Specimens from southern Illinois are smaller (5–7 mm.) and paler, the square black spots of the connexivum often reduced to rufous shades on a yellowish ground-color, while those from central Illinois measure 7–8.5 mm. and are usually darker, with distinct black connexival spots. One specimen, evidently this species, has the antenna black except the basal joint. Dubois, Carbondale, Alto Pass, Cobden, Parker, Dongola, Brownfield (S. Ill); Urbana and Seymour (C. Ill.)—June 7–22, July 3, 16, 17, 18, August 24, 30, and October 7. On the latter date they were abundant near Urbana in all stages, and Van Duzee so found them near Buffalo, N. Y., November 3. The food plant is the common wild carrot.

10. Neottiglossa Kirby

[This genus and Aelia are exceptions to the general rule in this subfamily in having the prothorax produced anteriorly on venter in the form of a thin plate on each side, each plate being reflexed near its inner margin and continued caudally in the form of an erect slender ridge as in Scutellerinae. The other structures in the genera are, however, similar to those of the Pentatominae, and as the nymphs agree better with those of the latter than with Scutellerinae, in having the anterior tergal scent-glands in line with the posterior pairs, it appears to me inadvisable with the available data to suggest any change in the subfamily arrangement.]

Key to Species

NYMPHS

Dorsal surface of head evenly rounded.....*sulcifrons.*

Dorsal surface of head with a large circular depression on disc.....*cavifrons.*

IMAGINES

Head dorsally evenly convex transversely and longitudinally, at sides narrowly elevated above lateral carina; general color pale, fusco-punctate; head with pale median line.....*undata.*

Head dorsally each side in front of eyes very tumid and greatly elevated above lateral carina; colors testaceous and black; head black, often with a testaceous mark each side, but without pale median line.

Deflexed anterior part of head flattened, uneven, slightly impressed on tylus; scutellum broadly testaceous laterally, the base and a median stripe broadly black ..... *sulcifrons.*

Deflexed anterior part of head occupied by a subcircular evenly concave densely punctate excavation; scutellum black, often with narrow pale margin on apical portion..... *cavifrons.*

Neottiglossa undata Say

Pentatoma undata Say, Descrip. Heter. Hemip. N. A., 1831; Compl. Writ. Ent. N. A., Vol. 1, p. 319.

Quebec to Vancouver, south to Col., Neb., Ill., and N. J., common in northeastern U. S. Algonquin (N. Ill.); Havana, Bloomington, Normal, Champaign, Urbana, St. Joseph, Homer, and Oakwood (C. Ill.); none taken in southern Illinois. Taken in Iowa on mullein. The imagines were all captured in April, May, and June except a few in November.

Neottiglossa sulcifrons Stål

Neottiglossa sulcifrons Stål, Enum. Hemip., Pt. 2, p. 18. 1872.

A southern species, ranging north as far as Utah, Nebraska, Iowa, and the District of Columbia. It occurs in southern Illinois, and is also taken in the central Illinois sand-regions at Havana and Forest City. The southern Illinois localities are Plainview, Carbondale, Makanda, and Cobden. Taken later than the preceding species—May to August.

Neottiglossa cavifrons Stål

Neottiglossa cavifrons Stål, Enum. Hemip. Pt. 2, p. 18. 1872.

This species is quite rare in collections, but is not uncommon in southern Illinois. It is listed from Texas, Utah, and California. The Illinois localities are Odin, Ashley, Dubois, Carbondale, Makanda, Anna, and Dongola, all in the southern fourth of the state. The dates range from April 28 to July 21, with nymphs on June 20 and July 9. One of these was taken on Pycnanthemum. The species is quite distinct from *sulcifrons.*

11. Murgantia Stål

Murgantia histrionica Hahn

Strachia histrionica Hahn, Wanz. Ins., Vol. 2, p. 116. 1834.

This is a common pest of cabbage and other Cruciferae in the South and in extreme southern Illinois, but it is seldom taken north of the center of the state. It has been known to feed on corn and a few other plants, probably in the absence of its natural food. It requires, of course, a spray of contact poison, and since it is very resistant to such treatment it is a difficult pest to combat. We have it from Willard, Grand Tower, Aldridge, Murphysboro, Anna, Metropolis, Mascoutah, and Edgewood in

southern Illinois, on cabbage, rape, turnip, and wild peppergrass, May 16 and 23, June 2, July 24 and 25, August 3, 5, 6, 10, and 11; and from Edgar, Urbana, and Springfield (C. Ill.) June 23, September 8 to 28, and in October, both young and old having been found on rape at Urbana and imagines on mustard at Edgar. The Bolter Collection contains one example from northern Illinois, and the species has been taken by us in Chicago. It is listed from Iowa (Stoner).

12. Cosmopepla Stål

Cosmopepla bimaculata Thom.*

Pentatoma bimaculata Thomas, Trans. Ill. State Agr. Soc., Vol. 5, p. 455. 1865.

Cimex carnifex Fabricius, Ent. Syst., Suppl., p. 535. 1798. (Preoccupied.)

Cosmopepla lintneriana Kirkaldy, Cat. Hemip. (Heter.), with Biol. and Anatom. Ref., Vol. 1, p. 80. 1909.

Abundant and generally distributed in Illinois. Taken in every month from March to November. Unlike most species it was most frequently taken in the summer months. Nymphs were collected in June and August. Kirkaldy lists as food plants, *Scrophularia nodosa,* Ranunculus, currant, blackberry, mint, mullein, potato, raspberry, and moth mullein; and to these I add from our records Stachys and pokeberry. The recorded range is the United states and Canada east of the Rocky Mountains, also Washington. We have several typical specimens from Monterey, Mex., and two from New Mexico.

13. Mormidea A. & S.

Mormidea lugens Fabr.

Cimex lugens Fabricius, Ent. Syst., sec. ed., Vol. 4, p. 125. 1794.

This species also is abundant in all sections of Illinois. Common in the United States and Canada, especially east of the Rocky Mountains. Like the preceding species it is notably most abundant in the summer months. Nymphs also were common in summer after June 21, and a few were taken in September and October. Imagines occurred in November, December, March, and April, indicating hibernation as adult. Food plant, Verbascum (Kirkaldy).

14. Solubea Bergr.

Solubea pugnax Fabr.

Cimex pugnax Fabricius, Ent. Syst., sec. ed., Vol. 4, p. 100. 1794.

A southern and tropical species (Pl. XXI, Fig. 78). It ranges from Long Island to Iowa, thence to Brazil. It has not been taken in northern Illinois and only rarely in central Illinois (at Urbana, Mahomet, and Topeka), but it is very common in the state south of the latitude of St. Louis. It is recognized as a pest of grasses in Kentucky,* and corn,

[* The synonymy herewith is that given by Van Duzee in his recent Catalogue. Mr. Hart used the name *lintneriana* in his MS.]

* Garman. *Psyche,* Vol. 6, p. 61.

wheat, Panicum, and Setaria are listed as food plants. We have taken it from May to November, especially in midsummer; the nymphs from July to October. It is also recorded as attacking the cotton-worm (Aletia).

15. Proxys Spin.

Proxys punctulatus P. B.

Halys punctulata Palisot de Beauvois, Ins. rec. en Afr. et en Amér., p. 188. 1805.

This species ranges from Florida to Oklahoma and Texas, and southward into Central America, with one record for Philadelphia. The species was taken by the author in extreme southern Illinois June 4 to 10, at Parker, Pulaski, and Cairo, in the latter place under electric street-lights. The food plant is given as cotton, but there is very little or none of this in the vicinity of the localities named. It is also said to prey upon the cotton-worm.

16. Prionosoma Uhl.

Prionosoma podopioides Uhl.

Prionosoma podopioides Uhler, Proc. Ent. Soc. Phil., Vol 2, p. 364. 1863.

The range usually recorded for this species is from western Canada to Lower California, west of the Rocky Mountains. Stoner records it, however, from Iowa City and Ft. Madison, Iowa, in sandy ground. Since the latter locality is on the Mississippi River opposite Illinois the species should be looked for in the extensive sand-regions on the Illinois side of the Mississippi in this vicinity.

[There is one specimen without a locality label in our collection.]

17. Menecles Stål

Menecles insertus Say

Pentatoma inserta Say, Descrip. n. sp. Heter. Hemip. N. A., 1831; Compl. Writ., Ent. N. A., Vol. 1, p. 317.

Recorded from Canada, and ranging across the northern United States from Massachusetts to California, south as far as Arkansas. "Apparently nowhere abundant." (V. D.) In our collection from northern Illinois; from Quincy, White Heath, Urbana, St. Joseph, Homer, Muncie, and Hillery, in central Illinois; and from Dubois and Anna (S. Ill.). Nymphs in June; imagines from March to November. Its infrequency in collections is doubtless due to its arboreal habits. Van Duzee records its capture in numbers from small hickory trees; and in late October and early November we found it very abundant on sidewalks on the campus of the University of Illinois under a row of hard maple trees, which it was presumably leaving for hibernation.

18. Euschistus Dall *

The structure of the male hypopygia in this genus is similar in all of the species, the principal distinctions being found in the shape of the

[* The key, with the exception of the bracketed matter, is by Mr. Hart. The remainder of the text, including records and description of species, is by the editor.]

ventral plate, as shown in Figures 34 to 39, Plate XVIII. The form of this plate in *impictiventris, euschistoides, ictericus,* and *servus* is almost identical, the central emargination being almost evenly rounded off laterally. In addition to this character all of the species of this group have a distinct central notch in the thin plate which projects from the caudal margin of the upper plate of the hypopygium, the notch varying slightly in depth in the different species (Fig. 37). The two species *tristigmus* and *pyrrhocerus* have the hypopygia of slightly different form, the ventral plate having a slight but distinct angle at each side of the central emargination, and the thin plate above referred to sharply produced in center, not notched (Fig. 35). Other forms of the hypopygial structures are shown in Figures 34, 36, 38, and 39.

Key to Species

A distinct black dot in each anterior angle of the ventral segments.†

[Juga with a few sparse punctures along the lateral margins and between ocelli; disc of pronotum and elytra largely impunctate; antennae pale..... .....*subimpunctatus.*]

Juga above densely punctate; in side view obliquely truncate, not exceeding the obtuse median anterior profile formed by the tylus and labrum; margin of male genital segment, as viewed from behind, with distinctly limited median notch; antennae usually pale or reddish; 9 or 10 mm.

Side margin of pronotum nearly straight to the obtuse lateral angles, an evident pale edge, sharply contrasting above with a well-defined dark border; head above with dark margin; no median ventral spots; notch in male genital segment V-shaped, a similar, very small incision each side of it.....*politus.*

Side margin of pronotum deeply sinuate, pale edge narrow, dark border shading off very gradually inwards, none on head; venter in front of genital segment with one or more median spots, rarely none; last tarsal usually black-tipped; notch in male genital segment semicircular, limited each side by a small tooth.

Lateral pronotal angles rounded or subacute; ventral spots 2–4; darker, antennae often black apically; imagines common before and after July.. .....*tristigmus.*

Lateral angles spinose or acute; ventral spots 0–2; paler, antennae pale; common southward, especially during July.....*pyrrhocerus.*

Juga above rather sparsely punctate along the middle of the disc; margin of male genital segment, viewed from behind, broadly concave without definitely limited notch; antennae pale or apically black; length abut 12 or 13 mm.

Juga in side view acutely projecting more or less beyond the median profile, as seen from above usually exceeding tylus; male genital segment without black spot; width across elytra 7–8 mm.

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† Turn apex of abdomen to the light to avoid shadows at the anterior angles.

Apical notch between juga shallow; connexivum partly exposed beyond elytral margin; antennae pale or reddish; margino-ventral dots elongate, invading adjacent hind angles of preceding segment; legs feebly dotted; lateral pronotal angles acute or subspinose.....*servus.*

Apical notch deep; connexivum covered by elytra; antennae black apically; margino-ventral dots not evidently invading hind angles of preceding segment; legs strongly dotted; lateral pronotal angles rounded or subacute .....*euschistoides.*

Juga in side view hardly exceeding median profile, and as seen from above not exceeding tylus; male genital segment with mediobasal rounded black spot; antennae apically black; width across elytra 6 or 7 mm.; lateral pronotal angles acute or subspinose.....*variolarius*, var.

No black dot in the anterior angles of the ventral segment; juga in side view hardly exceeding medial profile, and as seen from above not exceeding tylus; antennae apically black; width across elytra 6 or 7 mm.; lateral pronotal angles acute or subspinose.

No evident raised smooth interhumeral line; spiracular rings pale; male genital segment with mediobasal rounded black spot; [no small black dots on disc of venter of thorax].....*variolarius.*

An evident smooth interhumeral line, usually raised; spiracular rings black; male genital segment without spot; [4 small black dots on each side of disc of thoracic venter].....*icterieus.*

Euschistus subimpunctatus, n. sp.

Female.—Yellowish testaceous, dorsum with brown punctures. Antennae slightly reddish on apical half; rostrum black on greater portion of apical joint. Venter of thorax with the usual 5 black dots on each side, 4 of which are on disc. Abdomen without black median ventral spots; extreme apices and bases of lateral margins of ventral segments glossy black; dorsum dark brown, with a subquadrate pale spot in middle of lateral margin of each segment. Membrane of wings unspotted. Legs with minute brown spots at bases of the setulae.

Tylus as long as juga, slightly pointed in front, the juga narrowed anteriorly, their lateral margins sinuate; second antennal joint a little shorter than third; dorsum of head almost impunctate, only a few scattered punctures along margins and between ocelli; ventral surface almost impunctate. Pronotum with rather large but not dense punctures on lateral margins and on median two-thirds of posterior margin, the remainder impunctate except for a few sparse punctures in middle near anterior margin; lateral margins slightly sinuate, with a few small protuberances on anterior half, not vertically rugose, posterior lateral angles produced in the form of a short tooth which is not so acute as in *pyrrhocerus;* scutellum with a large group of punctures on middle of each lateral margin; venter of thorax sparsely punctate. Elytra very sparsely punctate along inner margin, with rather close punctures on outer portion beyond vein, and with a few punctures at apex. Venter of abdomen with very small punctures, basal genital plates sinuate on their apical margin,

the inner apical angle slightly produced, the general habitus as in *euschistoides*.

Length, 11.5 mm.

Type, Anna, Ill., July 22, 1883. One specimen.

This species differs from any other Euschistus known to me in having the dorsum very sparsely punctate.

I found this specimen among some material that Mr. Hart had not incorporated in the collection.

Euschistus politus Uhl.

Euschistus politus Uhler, Can. Ent., Vol. 29, p. 117. 1897.

This species has been recorded by Uhler from Massachusetts, Rhode Island, Pennsylvania, Maryland, and the District of Columbia. It has been recorded by other workers from Ohio, New Jersey, and New Hampshire.

In our collection there is a male from Dubois—August 19; one female from Muncie—July 6; another from northern Illinois; and one without locality which is labeled "*Euschistus pallidus* Uhler MS."

In addition to these, there is a much darker female specimen from Minnesota, labeled by Mr. Hart "*politus?*"

Euschistus tristigmus Say

Pentatoma tristigma Say, Descrip. n. sp. Heter. Hemip. N. A., 1831; Compl. Writ. Ent. N. A., Vol. 1, p. 314.

Recorded from northern Canada to southern Mexico. Distributed generally throughout Illinois but more common in the northern half of the state. Our specimens bear various dates ranging from April 11 to November 12, all the intervening months being represented. We have in addition to Illinois examples, specimens from Wisconsin, District of Columbia, New York, and Minnesota.

The editor is of the opinion that *luridus* Dallas is distinct from *tristigmus* Say. The regularly rounded humeri of the former are very conspicuously different from the angular ones of *tristigmus*, and with the naked eye it is possible to recognize the forms very readily. The apical two antennal joints in *luridus* are usually conspicuously darker than the others, but this character is not a dependable one.

The typical form of *tristigmus* is common in the southern half of Illinois, while *luridus* is found in the northern portion, our localities including Algonquin, Chicago, and Savanna. We have specimens of *luridus* from Buffalo, N. Y., Omaha, Neb., Duluth, Minn., and Lone Rock, Wis.

Euschistus pyrrhocerus H.-S.

Cimex pyrrhocerus Herrich-Schaeffer, Wanz. Ins., Vol. 6, p. 71. 1842.

This form is considered as a variety of *tristigmus*, and appears to replace it to a very large extent in the southern portion of the United States. I consider *pyrrhocerus* a distinct species.

In Illinois we have found it common at Murphysboro, Cobden, Grand Tower, Pulaski, East St. Louis, Dubois, Clay City, and Havana, all south of the middle of the state. The most northern records we have for the form are Urbana and Hillery. The only months represented by our collections are June, July, and August.

Euschistus servus Say

Pentatoma serva Say, Descrip. n. sp. Heter. Hemip. N. A., 1831; Compl. Writ. Ent. N. A., Vol. 1, p. 314.

This species is cited by Van Duzee for the southeastern states as far north as New Jersey, and west to Texas, Kansas, and New Mexico.

In Illinois the species appears to be much more numerous in the southern portion of the state, ranging from Urbana southward, only two examples in our collection bearing the label "N. Ill." The dates on our specimens range from May 13 to August 25, and include all intervening months.

In addition to the Illinois material we have specimens from Alabama, Tennessee, Florida, and Texas.

In our collection there is a large series of specimens standing as *impictiventris* Stål, named by Mr. Hart. As the species is not in Mr. Hart's key I made a search to discover if any light could be thrown upon the omission by notes not contained in the manuscript. I find the following note in some manuscript not directly connected with the present work:

"My *impictiventris* is perhaps intermediate between *servus* and the true *inpictiventris*. These three forms, although usually distinguishable, intergrade so much that they are probably only geographic subspecies.

"*Pyrrhocerus* is usually considered a variety of *tristigmus*. The differences are similar to those in the group above mentioned, and although more marked and more constant than any in that group, are probably only of subspecific value."

As indicated above there is some doubt as to the specific distinctness of the forms, a fact borne out by a perusal of Van Duzee's notes on *impictiventris*.*

The specimens standing as *impictiventris* in our collection are from the same localities as those of *servus*, with the exception that the most northern examples are from Muncie. The dates range from June 28 to August 24. We also have specimens from Tennessee, Kansas, and California.

Euschistus euschistoides Voll.

Diceraeus euschistoides Vollenhoven, Versl. Med. Kong. Akad. Wetens. Amst., ser. 2, Vol. 2, p. 180. 1868.

Euschistus fissilis Uhler, Proc. Boston Soc. Nat. Hist., Vol. 14, p. 96. 1871.

This species is distributed throughout the North American continent from Quebec to Vancouver Island, and from Florida to Texas.

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* Trans. Am. Ent. Soc., Vol. 30, p. 45. 1904.

One of the commonest species in Illinois; generally distributed. Found in the imago stage throughout the year.

Euschistus variolarius P. B.

Pentatoma variolaria Palisot de Beauvois, Ins. rec. en Afr. et en Amér., p. 149. 1805.

This species is found almost everywhere in the United States and Canada, being especially abundant in the Northern States. It is the commonest species of the genus in Illinois, and is found in the imago stage throughout the year in all parts of the state.

The variety with black dots on lateral margins of abdomen included in the key is represented in our collection by three males and two females. Four of these are Illinois specimens, the locality labels reading, Ottawa, Carbondale, Dubois, and "N. Ill." One male is without label. The three specimens bearing dates were taken in July. Mr. W. L. McAtee has specimens of this variety from Riverhead, N. Y., West Cornwall and Westport, Conn., and from Mendham, N. J.

Euschistus ictericus Linn.

Cimex ictericus Linné, Cent. Ins. Rar., p. 16. 1763.

Found in the northern United States and Canada across the whole of the continent.

Our Illinois specimens are from Channel Lake, Beach, Cedar Lake, Algonquin, Lake Villa, La Prairie, and Urbana. The dates range from June 19 to August 14. We also have one specimen from Nantucket Island, Mass.

19. Hymenarcys A. & S.

Key to Species

Sides of thorax straight or slightly concave; lateral angles subacute; veins of membrane rarely anastomosing; spiracles distant from ventral margin about 1/2 length of segment; length 6.5–8 mm.....*aequalis.*

Sides of thorax evenly arcuate, lateral angles broadly rounded; veins of membrane freely anastomosing; spiracles distant from ventral margin about 3/4 length of segment; length 8.5–10 mm.....*nervosa.*

Hymenarcys aequalis Say

Pentatoma aequalis Say, Descrip. n. sp. Heter. Hemip. N. A., 1831; Compl. Writ. Ent. N. A., Vol. 1, p. 319.

This species tends to be somewhat southern in distribution, ranging from New York to Colorado and Montana and southward. It is quite abundant in southern and central Illinois, but there are very few records of it for the northern part of the state. Nymphs have been taken from May to August. We have taken the imagines in all the months from February to December, most abundantly from July to November. An imago was taken April 19 by E. O. G. Kelly under a corn husk.

Hymenarcys nervosa Say

Pentatoma nervosa Say, Descrip. n. sp. Heter. Hemip. N. A., 1831; Compl. Writ. Ent. N. A., Vol. 1, p. 321.

The range of this species is about the same as that of the preceding one, but it has been taken in Canada. Our collection contains specimens from numerous localities in southern and central Illinois, but none from northern Illinois. The nymphal dates are June 21 and 22 and July 17. Imagines have been taken from March to December, the occurrences being quite uniformly distributed through the period. Cotton is recorded as a food plant.

20. Coenus Dall.

Coenus delius Say

Pentatoma delia Say, Descrip. n. sp. Heter. Hemip. N. A., 1831; Compl. Writ. Ent. N. A., Vol. 1, p. 320.

This common species is widely distributed from Quebec to Vancouver, south to Florida and Texas, but is not numerous, and as Van Duzee says, is "apparently precinctive." Our collection shows numerous records for northern and central Illinois, but only one, Dubois, for southern Illinois, indicating that it is at least rare in the Ozarkian faunal district. Our nymphs were taken in June and July. The imagines were taken in every month from February to November, most abundantly, not in the summer months but in May and September. Olsen has kept imagines alive by feeding them on moth mullein *(Verbascum blattaria)*.

Subfamily *ACANTHOSOMINAE* *

There are but two genera of this subfamily recorded from North America. We have both genera represented in our collections.

The generic key which follows is based upon characters of the two species before me, and may not be serviceable in separating the other species.

Key to Genera

Pronotum slightly but distinctly produced posteriorly on caudal margin laterad of base of scutellum, not forming an angle from basal line to lateral angle of pronotum; osteole short and broad, not extending more than midway to margin of metathorax; basal genital plates of female much longer than broad, almost oblong ..... *Meadorus lateralis.*

Pronotum not produced caudad laterad of base of scutellum, forming a straight line from base to lateral angle of pronotum; osteole long and narrow, extending over two-thirds of the distance to margin of metathorax; basal genital plates of female as long as broad, subtriangular..... *Elasmostethus cruciatus.*

Meadorus lateralis Say

Edessa lateralis Say, Descrip. n. sp. Heter. Hemip. N. A., 1831; Compl. Writ. Ent. N. A., Vol. 1, p. 312.

This species has not been found so far as I am aware in Illinois, but as we have specimens in our collections from Lake Superior and Minne-

[* Treatment by editor.]

sota it is probable that it will be found in the northern part of the state. Our other specimens are from the following localities: Clark's Station and Colton, Cal., and Vancouver, B. C., all but the last being unmentioned in Van Duzee's Catalogue.

Elasmostethus cruciatus Say

Edessa cruciata Say, Descrip. n. sp. Heter. Hemip. N. A., 1831; Compl. Writ. Ent. N. A., Vol. 1, p. 311.

We have one specimen of this species from northern Illinois in our collections. Our other specimens are from the following localities: Spokane, Wash., Victoria, B. C., Texas, Yosemite Valley and Fresno Flats, Cal., Las Vegas, N. Mex., and District of Columbia. With the exception of New Mexico and British Columbia Van Duzee gives none of these localities.

Subfamily *ASOPINAE*

The members of this subfamily have very stout beaks, and are predaceous upon various insects, especially soft-bodied caterpillars and grubs, and are sufficiently abundant to render valuable service in destroying injurious larvae.

Key to Genera

Fore femora with small spine beneath, near outer third or fourth, the spine often blunt at apex, minute but distinct in Andrallus; male with silky-pubescent patch on venter each side of middle, except in Alcaeorrhynchus.

Pronotal lateral angles rounded; frena about 1/2 length of scutellum or less, apical part of scutellum U-shaped; above black or dark brown, with pattern of red to pale yellow markings.

Ventral spine reaching middle coxae.

Scutellum as a whole nearly U-shaped, frena about 1/4 its length, apical part over twice as wide as elytra (Discocerini Schouteden) . 1. *Stiretrus.*

Scutellum subtriangular, frena about 1/2 its length, apical part not wider than elytra (Tex., Ariz.) ..... *Oplomus* Spin.

Ventral spine not passing hind coxae ..... 2. *Perillus.*

Pronotal lateral angles sharply and prominently spinose, a small spine behind these; frena nearly 2/3 length of scutellum, apical part of scutellum small, subacute; above brownish, mostly vaguely marked.

Second ventral at middle with a broad flattened tubercle, its apex rounded-truncate; femoral spine evident; male without pubescent patches on venter—Fla., Trop. Am. (Mutyca Stål) ..... *Alcaeorrhynchus* Bergr.

Second ventral at middle with a low subconical prominence, femoral spine minute; male with pair of pubescent patches on venter (Tex., Mex.) .... 3. *Andrallus.*

Fore femora without trace of spine beneath, near the outer third or fourth.

[Head nearly as long as pronotum, juga exceeding tylus; pronotum with 2 angular protuberances on posterior lateral angle; eyes not contiguous to anterior margin of pronotum (Tex.) ..... *Heterosceloides* Sch.]

[Head much shorter than pronotum, the latter with at most 1 protuberance on lateral angle; eyes usually contiguous to anterior margin of pronotum.]

Second ventral in side view with distinct spine or tubercle projecting anteriorly towards or between hind coxae.

Fourth rostral about as long as third; above gray to brown. 4. *Apateticus.**

Fourth rostral about twice as long as third; above black with red or yellow pattern ..... 5. *Mineus.*

Second ventral in side view with not more than a slight obtuse angulation at middle.

Juga not meeting in front of tylus; osteole with distinct curved prolongation; bucculae not overhanging behind.

Second rostral 1/2 longer than third; metallic dark blue above..... ..... 6. *Zicrona.*

Second rostral more than twice as long as third; metallic blue to green above, with red to brown markings (Pa., Tenn., and southward, Trop. Am.) ..... *Euthyrhynchus* Dall.

Juga meeting in front of tylus; osteolar prolongation subobsolete; bucculae strongly elevated, in side view overhanging behind..... ..... 7. *Rhacognathus.*

1. Stiretrus Lap.

Stiretrus anchorago, var. fimbriatus Say

Tetyra fimbriata Say, Am. Ent., Vol. 3, 1828; Compl. Writ. Ent. N. A., Vol. 1, p. 93.

The species occurs in the Southern States, ranging north as far as Iowa and Massachusetts, and south to Panama. It is uncommon in Illinois so far as our experience goes. There are several specimens from northern Illinois in the Bolter Collection, and we have it from Algonquin (N. Ill.; Nason), Charleston (C. Ill.; C. C. Adams), and Thebes (S. Ill.; C. A. Hart), July 3 and August 23. The variety *violaceus* is known from Pennsylvania, and should be looked for in southern Illinois.

2. Perillus Stål

The species of this genus are black, varied with reddish, and marked with red, carmine, or pale yellow, notably a pale or red U- or V-shaped scutellar border. My material is not any too extensive, as the species are not usually abundant; but the pattern seems fairly constant, and I have ventured to use it freely in the following key.

Key to Species

Pronotum with anterior transverse black bar not interrupted at middle; costal border of corium pale; femoral spine a small tooth or tubercle, not longer than thick; basal margin of scutellum black..... *exaptus.*

[* See Addenda for generic subdivisions.]

Pronotum with a median pale vitta from anterior pale border, dividing anterior black bar into two transverse marks; costal pattern variable; femoral spine finger-like, longer than thick; basal margin of scutellum narrowly pale.

Second antennal black, venter with submarginal row of black spots (female) or a large central black patch containing the stridulatory areas (male); a broad distinct arcuate pale band between the humeri.

Black, with red markings; elytra black, costal border red towards base.... .....*bioculatus.*

More or less rufous or brownish, with pale yellowish markings; corium with broad pale costal, apical, and inner border, except inner margin, which is narrowly black.....*bioculatus*, var. *clauda.*

Second antennal pale, venter with broad submarginal black stripe; pale band between humeri absent, obscure, or irregular, costal border of corium pale, often a pale streak near inner margin.....*circumcinctus.*

Perillus exaptus Say

Pentatoma exapta Say, Jour. Acad. Nat. Sci., Phil., Vol. 4, p. 313. 1825.

Quebec to Vancouver, southward to New Jersey and New Mexico. In our collections from northern Illinois and from Urbana, early in the season.

Perillus bioculatus Fabr.

Cimex bioculatus Fabricius, Ent. Syst., sec. ed., Vol. 4, p. 120. 1794.

This species is listed as ranging from California and Oregon to Iowa. The typical form is in our collection from Algonquin (Nason). The variety *clauda* has not been taken in Illinois, as far as I know. The two forms appear to be quite constant and distinct, and are perhaps valid species.

Perillus circumcinctus Stål

Perillus circumcinctus Stål, Stett. Ent. Zeit., Vol. 23, p. 89. 1862.

Eastern United States and Canada, as far west as Manitoba and Missouri, and perhaps Mexico. Fergus Falls, Minn., July 10 (Zetek). In Illinois it seems to occur only in sandy areas. In the Illinois valley sand-region we have found it common on the low sumac *(Rhus canadensis illinoensis)* of the sands, associated with the larvae of *Blepharida rhois,* on which it was probably feeding. Our localities are northern Illinois (several specimens); the lake beach at Chicago; and Manito, Forest City, and Havana in the Illinois valley sands, the dates being April 28, June 6, 8, and 10.

3. Andrallus Bergr.

A fine example of *A. spinidens* was captured by me at Brownsville, Tex., and the genus is therefore included in the key as a member of our fauna. The single species inhabits Ethiopian Africa, Madagascar, Asia Minor, India, Java, Borneo, Australia, New Caledonia, Fiji, and Tahiti,

and, says Schroeder, "has even been reported by Stål from Mexico; but this habitat seems not to have been confirmed. Ellenrieder gives rice as the food plant.

4. Apateticus Dall.

Key to Species

Larger species, 14–20 mm. to tip of elytra; venter without median black spots; membrane without dark streak; female genital segment with three basal plates (Apoecilus).

Mediobasal genital lobe of female subquadrate; lower appendage of male broad, flattened, bent, upper appendage dissimilar, palpus-like, small, nearly straight, about half as long as lower; tuberculate plate not prolonged below appendages; connexivum usually covered by elytra; above pale brownish; lateral pronotal angles acute, 50°–60°.....*cynicus.*

Mediobasal genital lobe of female subtriangular; lower appendage of male, narrow, curved, upper appendage similar, about equally long; tuberculate plate prolonged in an obtuse horn below lower appendages; connexivum more or less visible from above, especially in the female.

Lateral pronotal angles acute, about 50°–60°; color as in *cynicus;* venter very coarsely dotted at punctures, black spots at marginal incisures.....*crocatus.*

Lateral pronotal angles about 90°; tips of juga, pronotum posteriorly, scutellum, and elytra blackish, the two latter mottled with red-brown; head and pronotum anteriorly more yellow-brown; venter not very coarsely dotted at punctures, spots at incisures extended inward along sutures.....*bracteatus.*

Smaller species, 8–13 mm.; female genital segment with two basal plates (Podisus).

No dark subapical streak in membrane nor medioventral black spots; lateral pronotal angles blunt, about 90°.....*placidus.*

A membranal dark streak and one or more medioventral black spots.

Lateral pronotal angles acute or spinose, the angle formed by the sides evidently less than 90°.

Hind femora immaculate; lateral pronotal angles acute or very narrowly rounded, edge immediately in front of angle strongly arcuate; ventral spine short; length usually less than 10 mm.....*modestus.*

Hind femora with two subapical black spots; lateral pronotal angles prolonged, spinose or subspinose; edge in front of angle concave or nearly straight; ventral spine longer; length usually over 10 mm.....*maculiventris.*

Lateral pronotal angles 90° or over; hind femora darker apically, or with subapical dark annulus; ventral spine very short; a dark spot or bar on disc of elytra and one on base of scutellum, besides others on pronotum; size of preceding species.....*serieventris.*

Apateticus [Apoecilus] cynicus Say *

Pentatoma cynica Say, Descrip. n. sp. Heter. Hemip. N. A., 1831; Compl. Writ. Ent. N. A., Vol. 1, p. 312.

Eastern United States and Canada, Tex. This species has been taken by us most frequently in northern Illinois near Chicago, and is quite often washed up by the waves along the beach of Lake Michigan. The author has taken it at electric street-lights in Urbana. Other localities are Galesburg and Dubois, the latter in southern Illinois. The dates range from May 31 to August 24.

Apateticus [Apoecilus] crocatus Uhl.

Podisus crocatus Uhler, Trans. Md. Acad. Sci., Vol. 1, p. 384. 1897.

The specimens agreeing with *bracteatus* quite closely in male and female genitalia but similar to *cynicus* in general color and pronotal lateral angles I am calling *crocatus,* accepting Van Duzee's identification of Uhler's species. This, Van Duzee suggests, may be the southern form of *bracteatus,* but the marked difference in pronotal angles as well as in color-pattern inclines me to accept it as a distinct species, especially since the localities do not indicate a southern distribution. The range of the species according to Van Duzee is in the Rocky Mountain region from Manitoba to Arizona. Our specimens are from Minnesota, Michigan, New York, Nantucket Island, and northern Illinois, one being from Chicago.

Apateticus [Apoecilus] bracteatus Fitch

Arma bracteata Fitch, Trans. N. Y. State Agr. Soc., Vol. 16, p. 336. 1856.

The six specimens in the Bolter Collection which I identify as this species are all from Victoria, Vancouver Island. The color-pattern and short pronotal angles make them easily separable from *crocatus,* although the male and female genitalia of the two species are very similar.

Apateticus [Podisus] placidus Uhl.

Podisus placidus Uhler, Am. Ent. and Bot., Vol. 2, p. 203. 1870.

The distribution of this species—Canada, Mass., N. Y., Mich., Iowa, Col. (V. D.), Minn. (Bol.)—indicates that it will probably be found in Illinois also. May–September (Olsen).

Apateticus [Podisus] modestus Dall.

Arma modesta Dallas, List of Specimens of Hemip. Ins. in Coll. Brit. Mus., Pt. 1, p. 101. 1851.

Common in the northeastern United States and Canada, and listed as far west as Vancouver, Montana, Colorado, and Mexico (V. D.). Our specimens are from Vancouver and Minnesota with the exception of four which are definitely labeled as from Illinois. One was found preying upon a caterpillar at Centralia (S. Ill.) August 7; another was taken at Urbana September 20. June–September (Olsen).

[*The bracketed names are inserted by the editor.]

Apateticus [Podisus] maculiventris Say

Pentatoma maculiventris Say, Descrip. n. sp. N. Am. Ins. found in La. by Joseph Barabino. Mar. 1831. Reprint, *Psyche*, Vol. 8, 1999, p. 307.

Ranges across the United States and Canada, commoner east of the Rockies. Found in all sections of Illinois from April 2 to November 22; nymphs, from May 28 to October 23; nymphs and imagines both most numerous in June and July and the first half of August. It is the most useful of our predaceous Hemiptera, and is frequently seen feeding on the larvae of the Colorado potato-beetle. We have also found it feeding on the 12-spotted cucumber-beetle *(Diabrotica 12-punctata)* and on the larvae of *Canarsia hammondi, Hyphantria textor,* and *Datana ministra.* The nymph, however, according to Olsen, is principally vegetarian, feeding on apple, etc. He gives as the food plant, *Onagra biennis.*

A. modestus and *serieventris* are quite close to *maculiventris* and recognizable more by a combination of characters than by any one character. *A. serieventris* has the shortest pronotal hind angles, and a vague dark pattern formed by unevenly aggregated dark punctures on a whitish or grayish ground-color. The legs and venter have the black markings most strongly developed. *A. modestus* has the least black on legs and venter; the pronotal side angles are never spinose as in *maculiventris,* but only acute, the two sides approaching at an angle of about 60° (2/3 of a right angle) instead of at approximately a right angle as in *serieventris.* The angles in *maculiventris* although usually spinose are often no darker than in *modestus,* but the distinctive feature of the angle in *modestus* seems to be that the anterior side of the angle is decidedly arcuate, while in *maculiventris* both sides are very nearly straight, or the anterior a little concave. *Modestus* averages a little smaller than *maculiventris,* but *serieventris* is about the same size.

Apateticus [Podisus] serieventris Uhl.

Podisus serieventris Uhler, Proc. Boston Soc. Nat. Hist., Vol. 14, p. 94. 1871.

I have little doubt that this is the true *serieventris* as described by Uhler. It is not at all common. Van Duzee reports it from Vancouver, Montana, and New Hampshire. We have it from the Lake Superior region, Vancouver, Wyoming, and Minnesota (Bol.); also from Michigan, and two from northern Illinois—one from the Lake Michigan shore near the Wisconsin line; Long Island; May–September. It feeds on larvae of *Callosamia promethea, Clisiocampa americana* and *disstria, Hyphantria cunea,* dead imagines of *Limenitis ursula* and *Pyrophila pyramidoides,* also *Apateticus cynicus* and *Menecles insertus,* and all stages of *Porthetria dispar* (Olsen).

5. Mineus Stål

Mineus strigipes H.-S.

Podisus strigipes Herrich-Schaeffer, Wanz. Ins., Vol. 9, p. 338. 1853.

New York to Georgia, Massachusetts, Ohio, Texas, New Mexico, Colorado. Examples are in the Bolter Collection from Florida and north-

ern Illinois; and we have it from Havana and Carbondale in Illinois. July 31, October 5, and December 13.

The ground-color is black, marked with red or orange. The scutellar mark is V-shaped; the costal margin is narrowly pale; the pronotum is black, with red median line and front and side border connecting with the scutellar mark.

6. Zicrona A. & S.

Zicrona caerulea Linn.

Cimex caeruleus Linné, Syst. Nat., ed. 10, Vol. 1, p. 445. 1758.

This beautiful metallic greenish, purplish, or bronzy black species may occur in Illinois. Although a western form, ranging from Idaho to New Mexico and California, it has been reported from Mt. Washington, N. H., and we have it from Michigan (Nason), identified by Osborn as the variety *cuprea;* but the color is purplish rather than bronzy.

7. Rhacognathus Fieb.

Rhacognathus americanus Stål

Rhacognathus americanus Stål, Enum. Hemip., Pt. 1, p. 33. 1870.

A rare species, listed only from Winnipeg (Can.), Illinois, and Ohio. The Bolter Collection contains five examples from northern Illinois.

Family CYDNIDAE

Key to Subfamilies

NYMPHS

Spiracles not included in the lateral plate, the two setae obliquely or transversely placed behind it, forming a triangle; mediodorsal plates of scent-glands distinct ..... Cydninae.

Spiracles and their setae included in the lateral plate, the three nearly a straight line; mediodorsal plates of scent-glands with at least the first and second confluent ..... Thyreocorinae.

IMAGINES

Scutellum of moderate size, subtriangular, not reaching tip of abdomen, frena long; corium exposed, broadly triangular; hind wing lobes about equal, separated by shallow notches ..... Cydninae.

Scutellum very large, covering abdomen to apex, frena short; corium largely membranous, the exposed opaque part narrow; hind wing lobes deeply incised, the second large and very prominent ..... Thyreocorinae.

Subfamily *CYDNINAE*

Key to Tribes

NYMPHS

Spiracular setae on segments 3–7 placed transversely * ..... *Sehirini.*

* I have not seen a nymph of this tribe; the character has merely been deduced by analogy from a comparative study of adults which in other species have this structure the same as in the nymphs.

Spiracular setae transverse on segment 7, but the larger (inner) seta on the 6th and preceding segments progressively moved forward, carrying the false suture before it, reaching the side of the spiracle on the 5th or 4th, and passing well in advance of it on the 3d.....*Cydnini.*

IMAGINES

Margin of head and lateral margin of pronotum above without bristles or spines; hamus present; [rostrum not lying between 2 parallel ridges on venter of prothorax].....*Sehirini.*

Margin of head and lateral margin of pronotum above with spines or bristly hairs; hamus absent; [rostrum lying between 2 parallel ridges on venter of prothorax].....*Cydnini.*

Tribe SEHIRINI

Key to Genera

IMAGINES

Lateral margin of pronotum and elytra ivory-white; veins of hind wings conspicuously dark and thick, hamus present; rostrum not attaining the abdomen; osteolar prolongation broad, curved, reaching two-thirds of the distance from orifice to body margin.....1. *Sehirus.*

Lateral margin of pronotum and body black; rostrum attaining middle of abdomen; head very large, subtriangular; osteolar scale placed far out on the episternum, near its outer margin (Tex.).....*Lobolophus* Bergr.

1. Sehirus A. & S. (Canthophorus M. & R.)

Sehirus cinctus P. B.

Pentatoma cincta Palisot de Beauvois, Ins. rec. en Afr. et en Amér., p. 114. 1805.

Canada to Mexico (V. D.). In our collection from several localities in northern Illinois, but in central Illinois only from the sandy region about Havana, where, many years ago, I saw it very abundant on the stems of the pale horsemint *(Monarda punctata)*. We have also taken it on sweet clover and Stachys. The dates are from April 8 to May 2, and from July 21 to August 22. The earlier period is no doubt that of hibernated individuals, and the interval one of nymphal development.

Tribe CYDNINI

Key to Genera

NYMPHS

Hind tibiae rather slender, not dilated apically; tergal plates alutaceous.....*Pangaeus.*

Hind tibiae thick, broadly dilated in apical half; tergal plates smooth and shining.....*Cyrtomenus.*

IMAGINES

Osteole with auricle or overhanging ledge, not extending to near body margin in a long narrow canal; apical part of media in hind wings joined to radiomedial stem, as usual.

No deep groove on head above, just within the reflected margin.

Hind tibiae slender, nearly straight, uniformly spined.

Pronotum not margined in front.....1. *Geotomus.*

Pronotum with impressed submarginal line in front, costal margin rarely with 3 or 4 setigerous punctures.....2. *Pangaeus.*

Hind tibiae strongly flattened and curved; lower side bristly, upper side beset with short stout spinules.....3. *Cyrtomenus.*

A distinct groove on head above, just within the recurved margin, beset with bristles and short spinules.

Pronotum distinctly margined in front.

Scutellum about as long as broad, tip acuminate (Cal.). *Macroporus* Uhler.

Scutellum longer than broad, tip narrowly rounded (Col., Tex.).....
.....*Homoloporus* Uhler.

Pronotum not distinctly margined in front.....4. *Aethus.*

Osteolar canal long, narrow, and distinct, reaching three-fourths of the way from orifice to body margin; head margin with row of short thick comb-teeth; [metasternum carried caudad in the form of a thin plate which is broadened laterally, covering 2 or 3 of the abdominal segments;] scutellar apex mucronate, apical part of media in hind wings not connected with radiomedial stem (Amnestini).....5. *Amnestus.*

1. Geotomus M. & R. (Melanaethus Uhl.)

Geotomus pennsylvanicus Sign.

Geotomus pennsylvanicus Signoret, Ann. Soc. Ent. Fr., Ser. 6, Vol. 3, p. 207. 1883.

Melanaethus picinus Uhler, Bul. U. S. Geol. and Geogr. Surv. Terr., Vol. 3, No. 2, p. 391. 1877. Preoccupied.

One specimen, Urbana, Oct. 21. Pa. (V. D.).

2. Pangaeus Stål

Pangaeus bilineatus Say

Cydnus bilineatus Say, Jour. Acad. Nat. Sci. Phil., Vol. 4, p. 315. 1825.

Eastern and Southern States to Texas and Utah, also Iowa and Oregon (V. D.), and Missouri and Arizona (Bol.). In our collections from numerous localities in central and southern Illinois, but from northern Illinois I find only a single example so labeled—in the Bolter Collection. The dates range from March 8 to June 30, and from August 18 to October 30.

[A group of nymphs found by Mr. Hart under a piece of board in a sandy hollow near Havana, Ill., August 19, have the head structure of Aethus imagines, but notwithstanding these structural details they are undoubtedly the nymphs of *Pangaeus bilineatus.* The above nymphs are

listed by Mr. Hart as *"Cydnus sp."* in his discussion of the sand insects of the Havana region.* I obtained one nymph at Urbana, September 10, 1917.]

3. Cyrtomenus A. & S.

Cyrtomenus mirabilis Perty

Cydnus mirabilis Perty, Del. Anim. Artic., p. 166. 1834.

S. C., Ga., Tex., N. M., S. Am. (V. D.). One example taken at street light, Cairo, Ill., August 1. Adults and numerous nymphs were sent me by Prof. E. L. Worsham from Georgia as injurious to the chufa, or edible sedge-root (*Cyperus esculentus* L.).

4. Aethus Dall.

Aethus obliquus Uhl.

Microporus obliquus Uhler, Prel. Rep. [1871] U. S. Geol. Surv. Montana, etc., p. 394. 1872.

Colorado, Utah, New Mexico, Texas (V. D.), Nebraska (Zimmer), Iowa (Stoner), New Jersey, Long Island (Davis), Rocky Mountains to Atlantic Coast (Vestal).† Two specimens in our collection from sandy areas near Havana, one from Texas, two from northern Illinois, and 8 from Oregon, Ill., June 21, 1917, taken under a board in a sand "blowout" by J. R. Malloch and the writer. All of Stoner's specimens found in the sand about the roots of a bunch-grass, *Sporobolus cryptandrus*.

5. Amnestus Dall.

The genital structures are extraordinarily unlike the usual heteropterous type. The sex which bears the large spine on fore or hind femora has been called the female; but, judging from analogy and from careful study of the genitalia, I consider it the male. [Unquestionably it is.] In this sex the anterior part of the pronotum is distinctly tumid and shining and very obsoletely punctulate, while the same area in the female is scarcely elevated above the posterior part, and its surface is distinctly punctulate. At least the two smaller species are occasionally taken at lights in considerable numbers. [The peculiar platelike extension of the metasternum, included as a character in the key, I have seen in no allied genus nor in Pentatomidae.]

Key to Species

Fore femora of male beneath with large sub-basal bifid spine; hind femora with small subapical spine; in female both unarmed; jugal spines 5 (sometimes 6 in *spinifrons*).

Pronotum piceous black, elytra concolorous or paler; spine of male hind femora well developed; length about 3 mm., breadth, 2 mm.....*spinifrons*.

Pronotum and elytra light ferruginous brown; spine of male hind femora very small; length about 2 mm., breadth 1¼ mm.....*pallidus*.

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* Bul. Ill. State Lab. Nat. Hist., Vol. 7, p. 239.

† Bul. Ill. State Lab. Nat. Hist., Vol. 10, p. 30.

Fore femora of male unarmed, hind femora with immense spine nearly half as long as tibia; female fore femora unarmed, hind femora with small but usually evident spine; jugal spines 4; color paler and size slightly less than in *pallidus* ..... *pusillus.*

Amnestus spinifrons Say

Cydnus spinifrons Say, Jour. Acad. Nat. Sci. Phil., Vol. 4, p. 316. 1825.

United States, west to Colorado and Texas (V. D.), Long Island (Olsen). Taken by us in central and northern Illinois from March to June 28, and also in November.

Amnestus pallidus Zimmer

Annectus [lapsus] *pallidus* Zimmer, Can. Ent., Vol. 42, p. 166. 1910.

Described from Kansas as *Annectus* (!) *pallidus*. In our collections from Algonquin (N. Ill.); Havana, Bloomington, Normal, Champaign and Urbana (C. Ill.); Centralia and Anna (S. Ill.). Dates from April 18 to June 19, and October 3 and 5 and December 4. Apparently the same species was taken in large numbers at a lamp in Fort Brown, Brownsville, Tex., in June.

Amnestus pusillus Uhl.

Amnestus pusillus Uhler, Bul. U. S. Geol. and Geogr. Surv. Terr., Vol. 1, No. 5, sec. ser., p. 278.

Common in the eastern United States, west to Kansas and Iowa, and also listed from Lower California and Trinidad (V. D.). The northernmost records are New Hampshire, New York, Indiana, and Iowa. It does not appear in our collections from northern Illinois, but has been taken at lights, and otherwise, in the central and southern parts of the state. It seems to occur later in summer than the other two species, the dates running from May 3 to August 20; also December 4.

The comb teeth of the head margin are paler and longer than those of *pallidus*, and the pronotal transverse impression is deeper than in that species. [A male taken at Urbana, August 20, 1914, has the spine on hind femur about as long as the femoral diameter.]

Subfamily *THYREOCORINAE* *

The negro-bugs are plentiful and sometimes cause serious injury to vegetation. Their oval to circular form, very large scutellum, black color, and beetle-like appearance make them readily identifiable in the field. The species are numerous and require considerable care in their separation.

Listed under the name Thyreocoris in Van Duzee's Catalogue are several well-marked groups which I consider are entitled to distinct generic rank. I have before me the European species *scarabaeoides* Linné, the genotype of Thyreocoris. There is no described American species that agrees with it in certain characters which appear to me as of generic importance in this family. I have drawn up a synopsis of the differentiat-

[* The following treatment of this subfamily is entirely by the editor.]

ing characters of the groups now listed as Thyreocoris and present it in the hope that it may cause some student of the family to investigate further into the status of these segregates.

Key to Genera

NYMPHS

Lateral margins of pronotum and bases of wing pads with a fringe of long hairs; hind tibia with 5 series of stout spines; spiracles not in straight series (Pl. XIX, Fig. 42) ..... *Cydnoides.*

Lateral margins of pronotum and bases of wing pads without a fringe of long hairs.

Spiracles * of all except the penultimate ventral segment in a straight row, the anterior one on every segment far removed from lateral margin (Fig. 40) .. .. *Galgupha.*

Spiracles on all segments in an angulated series, the anterior one very close to or in lateral margin on the third, fourth, and fifth visible segments (Fig. 41) ..... *Corimelaena.*

IMAGINES

Juga contiguous in front, obliterating tylus at apex; chitinized part of wing broad from base to apex, the apex broadly rounded, costa with a deep longitudinal groove from base to apex; femora without spines; hind tibia with a few short spines on antero-ventral, antero-dorsal, postero-dorsal, and postero-ventral surfaces, the spines much shorter than diameter of tibia; basal plate of female genital segments with a longitudinal central carina .... 1. *Thyreocoris, sens. str.*

Juga separated to apices; chitinized portion of wings narrowed very much from base to apices, or if not so the lateral margins of pronotum and of chitinized portions of wings are fringed with long hairs, the costa is rounded, without a longitudinal groove, or the hind tibia has 5 series of long spines.

Lateral margins of pronotum and of chitinized portions of wings with long hairs; apices of chitinized portions of wings obtuse; hind tibia with long spines on antero-ventral, anterior, antero-dorsal, postero-dorsal, and postero-ventral surfaces; at least fore and hind femora without spines. 2. *Cydnoides.*

Lateral margins of pronotum and of chitinized portions of wings without long hairs.

Femora with stout spines; hind tibia with long spines on five surfaces as in *Cydnoides*, the posterior surface with a linear ridge from base to apex on posterior surface; apices of chitinized portions of wings acute; the costa with a longitudinal groove ..... 3. *Galgupha.*

Femora with a few slender bristly hairs; hind tibia with very short widely placed spines on four surfaces, none on anterior surface, the posterior surface without a longitudinal ridge; costa without a longitudinal groove ..... 4. *Corimelaena.*

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* The term "Spiracles" in this connection includes the true spiracle and the two sensory setigerous punctures, the "anterior spiracular puncture" referred to under Corimelaena being the true spiracle.

1. Thyreocoris Schr.

I have before me several specimens of the genotype of Thyreocoris, which, as shown in synopsis in this paper, differs from all the other groups now listed under the same generic name.

2. Cydnoides, gen. n.

Differs from all other genera in the group in having the lateral margins of pronotum and of the greater portion of chitinized parts of wings fringed with long hairs; the femora of at least the fore and hind legs have bristly hairs on their antero-ventral surface but no stout spines; the chitinized portion of wings is broad to apex, the tip obtuse.

Genotype, *Corimelaena ciliata* Uhler.

Besides the genotype there are in our collections two other species, *renormata* Uhler and *sayi* V. D.; *obtusa* Uhler belongs to this genus, but I have not seen it.

Key to Species

Entirely black species with bronzy tinge, the surface of scutellum subopaque; mid femur with a few very short antero-ventral spines.....*ciliatus*.

At least a portion of the chitinized part of wings yellowish white; mid femur with a few moderately long bristly hairs on antero-ventral surface.

Head distinctly flattened on anterior half of dorsum; pronotum black; only the base of chitinized portion of wings white.....*renormatus*.

Head convex on dorsum; pronotum black with a brassy or greenish tinge, the lateral and posterior margins yellowish white; all of chitinized portions of wings white (Tex.).....*sayi*.

Cydnoides ciliatus (Uhl.)

Corimelaena ciliata Uhler, Proc. Ent. Soc. Phil., Vol. 2, p. 156. 1863.

Colorado, Kansas, Florida (V. D.). There is in Illinois a characteristic and very common species of the sand areas, taken at Bishop, Topeka, Havana, Meredosia, and Arenzville June 7 to October 29. In August it was often common on the stems of various plants, but its most curious habit was that of burrowing in the loose drifting sand about the roots of tufts of grass. Where there was no sign of individuals above ground, a single turn of the finger in the sand around a grass plant would frequently bring two or three to the surface. Nymphs were taken at Havana September 20, 1911.

Its finely wrinkled and punctate surface, make it very easily recognizable.

Cydnoides renormatus (Uhl.)

Corimelaena renormata Uhler, Hemip. Col., Bul. 31. Col. Agr. Exper. Sta., p. 11. 1895.

Colorado (V. D.). One male example from northern Illinois (S. H. Peabody).

Cydnoides sayi (Van Duzee)

Thyreocoris albipennis Say, Descrip. n. sp. Heter. Hemip. N. A., 1831; Compl. Writ. Ent. N. A., Vol. 1, p. 311.

Corimelaena sayi Van Duzee (n. n. for *albipennis*, preoc.), Trans. Am. Ent. Soc., Vol. 30, p. 10. 1904.

Van Duzee notes * Gillette's rediscovery of Say's *T. albipennis* in Colorado, proposing the name *sayi* in place of *albipennis*, the latter being preoccupied in the genus. I take this opportunity to extend its hitherto known range by recording the collection of three fine female specimens of *sayi* at Fort Brown, Brownsville, Tex., November 29 and December 9, 1910, by Mr. Hart.

3. Galgupha A. & S.

I have placed in this genus all entirely black species of Thyreocorinae which have the following characters: all the femora with short stout spines on the antero-ventral surface; the hind tibia with 5 series of spines and with a longitudinal carina from base to apex; and the spiracles on all abdominal segments except the last in a nearly straight row.

Key to Species

NYMPHS

Glossy black species; head almost entirely impunctate; abdomen glossy black except a narrow submarginal stripe on each side of dorsum and venter..... .....*denudata.*

Yellowish testaceous species, the dorsum of abdomen sometimes brown on the chitinized areas, if so the pale stripes are very broad; legs glossy black; head distinctly punctured on dorsum.....*nitiduloides.*

IMAGINES

Fore femur with 2 short stout spines on apical third of antero-ventral surface; fore tibia with 6 or 7 strong spines and 1 weak setula on antero-dorsal surface (Pl. XIX, Fig 50); chitinized portion of wing obtusely pointed at apex (Fig. 45); dorsum of head, pronotum, and scutellum shagreened, not highly polished, the punctures contiguous or subcontiguous on margins; hypopygial plate as in Figure 51; spiracular punctures not in straight series.....*nigra.*

Fore femur with at least 3 short spines; dorsum more or less distinctly polished; spiracular punctures in straight series; chitinized portion of wing acutely pointed at apex.

Scutellum acute at apex (Fig. 62); dorsum of head, pronotum, and scutellum very minutely and sparsely punctured except on margins; hypopygial plate of male as in *nigra*, but impunctate or almost so; fore femur and fore tibia as in *atra*..... .....*denudata.*

Scutellum rounded at apex (Fig. 63).

Hypopygial plate not over 3 times as broad as long (Fig. 49); fore femur with 3 antero-ventral spines, their length not strikingly dissimilar; fore tibia with 5 or 6 strong spines and 1 or 2 weak setulae on antero-dorsal surface (Fig 48); chitinized portion of wing as in Figure 57.....*atra.*

* Trans. Am. Ent. Soc., Vol. 30, p. 10.

Hypopygial plate much more than three times as wide as long; fore tibia with bristles on entire length of antero-dorsal surface, no weak setulae at apex.

Fore femur, with the median antero-ventral spine strikingly longer than the other two; fore tibia with 5 or 6 long stout spines and apicad of these 2 short ones on antero-dorsal surface (Fig. 46); hypopygial plate of male not strikingly concave on upper margin (Fig. 47); venation of chitinized portion of wing as in Figure 44; scutellum when viewed in profile not abruptly declivitous beyond middle (Fig. 55)) . . *nitiduloides.*

Fore femur with the first and second spines equal or subequal in size; fore tibia with 6 or 7 strong spines on antero-dorsal surface (Fig. 52); venation of chitinized portion of wing as in Figure 43; hypopygial plate very conspicuously concave on upper margin (Fig. 53); scutellum when viewed in profile rather abruptly declivitous beyond middle (Fig. 54) . . . . . *aterrima.*

Galgupha nigra Dall.

Corimelaena nigra Dallas, List of Specimens of Hemip. Ins. in Coll. Brit. Mus., Pt. 1, p. 57. 1851.

Canada and Colorado (V. D.). Brownsville, Tex. (Hart). Found throughout Illinois, but not common. Chicago, Savanna (N. Ill.); Urbana, Galesburg (C. Ill.); Grand Tower, Metropolis, (S. Ill.). The dates are notably late in the season—July 9 to October 17.

The species has nearly the form of *atra,* but is smaller, and is more opaque than either that species or *nitiduloides.* It is easily recognized by characters given in key, and by its almost subopaque color.

Galgupha denudata Uhler

Corimelaena denudata Uhler, Proc. Ent. Soc. Phil., Vol. 2, p. 157. 1863.

This species was originally described from a male obtained in Louisiana. I have before me a male imago and a nymph from Monterey, Mexico, July 5, 1908.

Galgupha atra A. & S.

Galgupha atra Amyot and Serville, Hémip., p. 68. 1843.

Canada, U. S. to Kan. (V. D.); Me. (Parshley). In our collection from all sections of Illinois, and from Ky., Mo., Tex., and Col. Dates, April 8 to November 3; most numerous in June and July.

This species is much more obsoletely punctured than *nitiduloides,* and more polished.

Galgupha nitiduloides Wolff

Cimex nitiduloides Wolff, Icones Cimicum, Fasc. 3, p. 98. 1802.

More characteristic of the western fauna, but found occasionally throughout the East (V. D.), Me. (Parshley), Mex., Guatemala (Distant). Found throughout Illinois, but especially common at Dubois in southern Illinois. Taken from March 10 to December 10, being com-

monest in June and July. Nymphs were common at Dubois in August, 1917.

GALGUPHA ATERRIMA, sp. n.

Male and Female.—Similar in color to *nitiduloides*.

Structurally similar to *nitiduloides*, differing as stated in key, and also in having the tylus more distinctly beaded at apex above, and the upper margin of the hypopygial plate of male decidedly reflexed.

Length, 4.25–5 mm.

Type, Odin, Ill., May 12, 1902. Paratypes: Havana, Ill., August 15, 1907; Dongola, May 10, 1917; Normal, June 14, 1882; and one male without data. Allotypes: White Heath, June 18, 1906; Grand Tower, June 27, 1906; Urbana, June 30, 1888; Cobden, April 12, 1883; one labeled Southern Ill.; one labeled N. Ill.; and two without data. All the foregoing specimens with data are from Illinois. I have also before me a male and female from Beltsville, Md., April 30, 1916, and June 15, 1913 (W. L. McAtee).

This is very probably the species referred to by Van Duzee as *nitiduloides* var. in his Annotated List of the Pentatomidae, page 5.*

4. CORIMELAENA White

In addition to the characters listed in the key for the separation of Corimelaena from its allies, the chitinized portions of the wings present venational characters that are valuable. The costal region lacks the linear depressions that are so evident in the species of the other genera and only two distinct sutures are present, as indicated in Figure 56, Plate XIX. The scutellum differs from that of allied genera in having an impressed line on basal half near to lateral margins, and the pronotum is distinctly impressed near posterior lateral angle, causing its margin here to be nearly vertical.

KEY TO SPECIES

Chitinized portion of wing entirely black, punctate to lateral margin; basal genital plate of female about twice as wide as its greatest length; median transverse depression of pronotum very faint; fore tibia with 5 postero-dorsal spines in addition to the apical one..... *anthracina.*

Chitinized portion of wing partly yellow or white, or species not as above.

Hind tibia with 3 or 4 postero-dorsal spines, the basal one very small, close to base; if all spines are very small or absent the chitinized portion of wing is rounded at apex, and the pale color extends mesad of cubitus.

Large species, averaging 4 mm. in length; pale border of wing not broadened near base, or if so the apex of elytra is acute.

Pale border of wing not broadened near base; dorsum of pronotum with sparse large punctures and numerous very small interspersed punctures on disc.

Basal genital plates of female much wider than long (Pl. XIX, Fig 65); penultimate segment before genital plates without a lateral carina... ..... *polita*, sp. n.

* Trans. Am. Ent. Soc., 30, No. 1. 1904.

Basal genital plates of female as broad as long (Fig. 64); penultimate segment before genital plates with a sharp lateral carina; male hypopygial plate as in Figure 59.....*lateralis.*

Pale border of wing broadened near base, the pale margin very noticeably punctate; hypopygial plate as in Figure 61; dorsum of pronotum with large closely placed punctures on entire disc (Neb., Col., Ut., Wyo., Cal., Wash., Ariz.) .....*montana.*

Smaller species, rarely over 3 mm. in length; pale border of wing always broadened near base, apex of chitinized portion rounded.

Anterior margin of pronotum as distinctly punctured as posterior portion of head; hypopygial plate of male (Fig. 60) narrow, slightly emarginate above, with an overhanging lip or flange on each lateral third, the central third of disc usually highly glossy and impunctate, seen from above the areas on each side of caudal opening are each as broad as the opening; female genital plates broader than long; anterior spiracular puncture just clear of margin on all segments of abdomen; scutellum usually a little pointed at apex.....*pulicaria.*

Anterior margin of pronotum with the punctures very much smaller and weaker than those on posterior portion of head—subobsolete.

Pronotum highly polished, the punctures almost obsolete; hypopygial plate of male similar to that of *harti*, but the central elevation of upper margin is less developed and the disc is closely punctured throughout; the whitish yellow mark on wing is broadly interrupted in center; tibiae almost black, the spinules on postero-dorsal surface of hind pair strong.....*interrupta.*

Pronotum not highly polished, microscopically shagreened, the punctures distinct but small, shallow, and closely placed on anterior third; hypopygial plate of male broadly emarginate above, with less evident lateral flange than in *pulicaria;* pale mark on wing complete, broader than in *pulicaria;* tibiae yellowish testaceous, the spinules on hind pair minute.....*minutissima.*

Hind tibia without postero-dorsal spinules, rarely with minute setulae present; chitinized portion of wing acute at apex.

Scutellum about as broad as long, without indication of a central impunctate longitudinal line; yellow margin of wing not extending mesad of cubital vein; anterior abdominal spiracular puncture mesad of lateral carina.

Smaller species, averaging 2.5 mm. in length; hypopygial plate of male entirely black.

Head almost angularly emarginate in front of eyes, more pronouncedly so in male (Pl. XX, Fig. 68); male hypopygial plate with broad central emargination; female genital plates broader than long...*nanella.*

Head not almost angularly emarginate in front of eyes, slightly concave (Fig. 67); male hypopygial plate doubly emarginate (Pl. XIX, Fig. 58); female genital plates subtriangular (Fig. 66).....*harti.*

Larger species, averaging from 3 to 4 mm. in length; hypopygial plate in male yellowish along upper margin, the outline broadly concave, with

a less pronounced central projection than in *harti;* female genital plates as in *harti;* hind tibia frequently with 1 or 2 weak postero-dorsal setulae.....*agrella.*

Scutellum distinctly longer than broad, with a more or less distinct impunctate longitudinal central line; yellow margin of wing extending mesad of cubitus; female genital plates similar to those of *harti* but more broadly punctate; male hypopygial plate similar to that of *pulicaria* but regularly punctate on entire surface and not so much reflexed laterally; anterior abdominal spiracular puncture in lateral carina except in basal series (Col., Utah, Dak., Ariz., Ore., Mexico).....*extensa.*

Corimelaena anthracina Uhler

Corimelaena anthracina Uhler, Bul. U. S. Geol. and Geogr. Surv. Terr., Vol. 1, No. 5, sec. ser., p. 270. 1876.

Despite the black color of this species it belongs to Corimelaena and is separable from its allies as indicated in key. It has not been taken in Illinois as far as our records show, but we have a specimen labeled "L. Sup." (Lake Superior), and it is possible that it occurs in the northern part of the state.

Corimelaena polita, sp. n.

Female.—Similar in color to *lateralis,* the two segments anterior to genital plates with pale yellow border.

Structurally similar to *lateralis,* differing as follows: the head is more narrowed anteriorly, the sides in front of eyes are more noticeably sinuated, the tylus is slightly longer than the juga, its surface convex anteriorly, glossy and almost impunctate; dorsum of pronotum with large punctures on lateral margins, in transverse depression, and on disc behind the latter, otherwise with small subobsolete punctures. Scutellum more sparsely punctate than in *lateralis.* Genital plates as in Figure 65, Plate XIX. For other details see key.

Length, 4 mm.

Type, Brownsville, Tex., July 10, 1908.

I have no males of this species before me.

Corimelaena lateralis Fabr.

Tetyra lateralis Fabricius, Syst. Rhyng., p. 142. 1803.

Widely distributed but usually not abundant; not as common as *pulicaria.* N. J., Md., D. C., Ohio, Okl., Tex. (V. D.); Brownsville, Tex. (Hart); Chicago, Algonquin, Rock Island (N. Ill.); Arenzville, Homer, and Muncie (C. Ill.); Grand Tower, Carbondale, Makanda, and Pulaski (S. Ill.). April 24 to September 11.

The chitinized portions of wings have an even, narrow ivory-white border. In seven of the specimens this border is widely interrupted at middle and nearly obsolete anteriorly, only the posterior fourth remaining evident.

Corimelaena pulicaria Germ.

Odontoscelis pulicarius Germar, Zeit. f. Ent., Vol. 1, p. 39. 1839.

Very common and widely distributed (V. D.). Taken in numerous localities in all parts of Illinois, March 4 to October 6; common from April to August; nymphs in June, July, and August. Our commonest species.

Dr. S. A. Forbes says of this species*: "The favorite food plants of the species seem to be New Jersey tea *(Ceanothus americanus)*, Spanish needles, and a small dooryard weed, *Veronica peregrina*. It is probable that the insect breeds principally on these plants. Wheat, blue-grass, strawberry, and celery have been injured by them, and they often occur on cultivated berries, to which they give a disagreeable taste. The species is single-brooded, and is widely distributed east of the Rocky Mountains. The adults hibernate and appear in early spring, laying eggs in May and June. The young which hatch from these eggs rarely fail to reach maturity by the early part of July, after which the adult insect is common until fall."

Corimelaena interrupta, sp. n.

Male.—Black, highly polished. Wing with a broad pale yellow margin which is widest near base, and broadly interrupted in middle by a blackish brown mark. Antennae yellowish brown. Legs glossy black, knees paler, tarsi yellowish.

Head much broader than long, dorsum with large, deep, subcontiguous punctures except on two small areas on middle of posterior margin; tylus broad apically, not reflexed; lateral margin of head in front of eyes slightly and regularly emarginate. Pronotum with a few faint striations and numerous very indistinct shallow punctures on disc, the large deep punctures confined to a patch on middle of each side, which does not extend to margin, and a few in the transverse depression. Scutellum highly glossy, the punctures large and rather closely placed laterally on basal half, very sparse and smaller on disc, the whole surface with a subobsolete secondary microscopic punctuation. Venter with large punctures laterally, almost impunctate on disc; penultimate segment without sharp lateral carina.

Length, 3 mm.

Type and paratype, Brownsville, Tex., November 23, 1911. Swept from pastures in South Texas Garden (C. A. Hart).

Corimelaena minutissima, sp. n.

Male.—Differs in color from the preceding species in having the antennae paler, the pronotum subopaque, the tibiae as pale as the tarsi, and the pale border of wing complete.

Head less glossy than in preceding species, the margin in front of eye slightly sinuate. Pronotum microscopically shagreened, with closely placed shallow punctures on anterior third, the large punctures as in preceding species, but extending to lateral margin, and the transverse

* Twenty-third Rep. State Ent. Ill., p. 116. 1905.

depression slightly striated in the punctate portion. Scutellum as in *interrupta*. Venter with a narrower impunctate discal area. Hind tibiae with very weak spinules.

Length, 2.5 mm.

Type, Sarita, Tex., December 1, 1911. Taken on sand hills (C. A. Hart).

CORIMELAENA NANELLA McAtee, sp. n.

This species is most easily separable from *pulicaria* by the small extent of pale color on the corium. Only the outer edge laterad of the cubital vein is so colored, while in *pulicaria* the triangular area between the cubitus, brachium, and claval suture, also is pale. I have seen no real intergradation between these types of coloration. *Nanella* averages smaller in size, ranging from 2 to 2.5 mm. The color is more metallic, being bronzy black, and the body is distinctly thicker than in *pulicaria*. This species is not a small form of the new species described below, because it has the broad brachial field characteristic of *lateralis* and *pulicaria*.

Type, a male, Virginia, near Plummers Island, Md., June 17, 1913, (W. L. McAtee). In writer's collection. Paratypes, two males: Beltsville, Md., June 15, 1913 (W. L. McAtee); and Chesapeake Beach, Md., June 18, 1914 (L. O. Jackson). Allotype, Forest Glen, Md., June 13, 1915 (W. L. McAtee).

To the above description, which is by Mr. McAtee, I add the details of structure in key.

CORIMELAENA HARTI, sp. n.

Male and Female.—Glossy black, apex of tylus, chitinized portion of wing laterad of the outer venational suture, lateral margin of abdominal segment beyond the exposed portion of wing in both sexes, and margin of apical segment of female yellow. Antennae yellowish testaceous. Legs black, tibiae castaneous, tarsi yellowish.

Male.—Head much broader than long, with large subcontiguous dorsal punctures, slightly sinuate in front of eye, subtruncate at apex, the tylus with a small round dorsal wart at apex. Pronotum with large and interspersed minute punctures on almost the entire dorsum, the transverse middle depression nearly absent, posterior margin slightly declivitous, so that there is a decided depression between pronotum and base of scutellum, the latter about as long as broad, the apex obtusely rounded, in type with a slight central emargination which may be abnormal, in profile with a slight angle at base of posterior half, the declivitous portion nearly straight, punctures large and deep, especially so laterally, the disc with smaller punctures. Apex of chitinized portion of wing acute, venational suture as in *lateralis*. Hypopygial plate densely punctate, its upper margin doubly emarginate (Pl. XIX, Fig. 58). Hind tibia without postero-dorsal spinules.

Female.—Similar to the male, but the apex of scutellum is regularly rounded. The basal genital plates are broad, with punctures on the upper half (Pl. XIX, Fig. 66).

Length, 2.5 mm.

Type and allotype, Makanda, Ill., June 26, 1909. Paratypes, two females, Plummers Island, Md., June 10, 1906 (W. L. McAtee), and June 30, 1907 (A. K. Fisher), and one female, Virginia, near Plummers Island, July 20, 1913 (W. D. Appel).

Corimelaena agrella McAtee, sp. n.

Body as broad across posterior part of abdomen as at humeri, very broadly rounded behind; thicker throughout than in *C. lateralis*. Transverse depression across middle of pronotum more conspicuous than in that species, pronotum more tumid, bulging downward more strongly before humeral angle; posterior margin of pronotum rather straight. Costa slightly incurved opposite point where claval suture disappears beneath scutellum, insect therefore appearing somewhat constricted at this level. Triangular area between cubitus, brachium, and claval suture much narrower than in *C. lateralis* and with fewer punctures. Color more greenish with brassy reflections.

Length, 3 to 4 mm.

To put the contrasts with *C. lateralis* in another way it may be said that that species is broadest at humeri, more narrowly rounded behind, not appearing constricted, and by no means as thick. The depression across pronotum and the humeral tumidity are less conspicuous. Brachial field broader and with more numerous punctures. Length, 3.5 to 4 mm.

Type, a male from Plummers Island, Md., May 18, 1913, W. L. McAtee (in writer's collection). Allotype, same locality, June 17, 1913, W. L. McAtee.

Other specimens examined: from Plummers Island, Md., April 26, 1908, May 4, 9, 1913, May 17, 1907, May 24, 1914, June 7, 1914, June 8, 17, 1913, August 19, 1906; from Maryland near Plummers Island, May 9, 18, 1913, May 10, 1916, May 23, 1915, May 24, 1914; from Great Falls, Va., May 19, 1915, W. L. McAtee.

To the above description, which is by Mr. McAtee, I add the structural and color details in the key, and record a male from Kentucky in our collection.

Addenda *

Addendum 1

Thyanta Stål

The species of this genus are remarkably alike in structure and with few exceptions very similar in color. The key presented herein is based upon specimens in our collection and includes all species of the genus described from North America except *pallidovirens* Stål, which may be a variety of *custator* Say. The localities cited in the key are those of the specimens in our collection.

[* In order to leave Mr. Hart's text as nearly as possible in its original form the editor has written the following addenda, hoping that the matter presented may prove useful to students of this family.]

Key to Species

1. Humeral angles produced in the form of acute spines—Figure 79, Plate XXI (N. M.) ..... *perditor* Fabricius.
— Humeri rounded or angulated, not produced in the form of acute spines...2
2. Species at least 8 mm. in length; hypopygial orifice usually small, claspers with lateral, or median, process very small, sometimes a mere angle *(custator)* 3
— Species much smaller, rarely 7 mm. in length; hypopygial orifice large, claspers with lateral, or median, process elongate, the clasper appearing furcate.....5
3. Ocelli exceptionally large, the distance between their lateral margin and inner margin of eye not greater than width of ocellus; male hypopygium with a large rounded protuberance just below upper margin of opening, without conspicuous concave area on each side at apex, claspers as in Figure 74, Plate XX; hairs on tibiae in both sexes moderately long, not noticeably irregular as in *custator* (Tex.) ..... *casta* Say.
— Ocelli small, the distance between their lateral margin and inner margin of eye distinctly greater than width of an ocellus; male hypopygium flattened for a considerable distance below upper margin of opening, with a conspicuous concave area on each side at apex, clasper as in Figure 73, Plate XX 4
4. Lateral margins of pronotum glossy black, vertically rugose; male hypopygium with a slight but distinct elevation in center of the upper margin (Fig. 70) ..... *calceata* Say
— Lateral margins of pronotum rarely black, not vertically rugose; male hypopygium with upper margin in center transverse or almost so (Fig. 75)... ..... *custator* Fabricius.
5. Osteolar canal not longer than the distance from its apex to lateral margin of mesosternum (Utah) ..... *rugulosa* Say.
— Osteolar canal much longer than the distance from its apex to lateral margin of mesonotum 6
6. Head much longer than its greatest width (Fig. 71); dorsum green, with conspicuous yellowish white longitudinal stripes on head, scutellum, and elytra; pronotum with a broad conspicuous median transverse depression ..... *elegans*, sp. n.
— Head as broad as long, or the dorsum is without yellowish white stripes and the pronotum has no well-defined median transverse depression.....7
7. Venter of abdomen in both sexes with a transverse row of black dots near the posterior margin of each segment; lateral margins of pronotum subcarinate only on posterior half or less; lower margin of hypopygial opening of male with a deep central V-shaped notch (Fig. 72); head with sides straight for a considerable distance; mesosternum with a large black patch on each side of central ridge (Tex.) ..... *punctiventris* V. D.
— Species without the above combination of characters; if the mesosternum has the black patches as above the pronotum is carinate on its lateral margins from posterior to near anterior margin and the head is not straight on sides; male hypopygium without notch.....8

8. Mesosternum with a large black patch on each side of central ridge; head as in Figure 69, Plate XX; pronotum sharply carinate on lateral margins from posterior to near anterior margin (Tex., Cal.).....*brevis* V. D.

9. Mesosternum without a black patch on each side of central ridge; head with sides straight for a considerable distance; pronotum with lateral margins sharply carinate only on posterior half or less (Tex.)...*antiguensis* West.

Thyanta elegans, sp. n.

Male and Female.—Pale green, marked with yellowish white. Head with a broad white stripe on each side of dorsum, the two covering the juga almost to apex, and a white stripe below each eye on venter. Pronotum with a narrow white line on each lateral margin, and a reddish transverse band between humeri in male, the transverse band conspicuously white in center in female; prosternum, mesosternum, and metasternum each with a white spot or stripe on each side; scutellum broadly white on each lateral margin and in center, the scutellar stripes margined internally with red; elytra with a rather broad white costal streak. Connexivum uniform green; venter whitish green, the punctures darker. Legs green; tarsal claws blackened on apical half.

Head convex above, very distinctly longer than broad; dorsal vein as in Figure 71; second antennal joint longer than third. Humeral margin angulated but not very sharp; pronotum with a very conspicuous broad transverse depression in center, the dorsum coarsely punctate except on the transverse pale line in female. Scutellum rather narrowly rounded at apex, coarsely punctate except on margins at base and apex. Elytra coarsely punctate, not appreciably rounded off basad at apex on outer side. Genital plates of female as in Figure 76; hypopygium of male as in Figure 77. Hairs on tibia long, many of them longer than diameter of tibia.

Length: male, 6 mm.; female, 7 mm.

Type, male, Loma, Texas, July 7, 1908. Allotype, Lake Lomalta, Tex., November 27, 1910.

This species is distinguished from every other in the genus by its striking green and white markings and much elongated head. The head of *T. brevis,* which is much broader, is shown in Figure 69.

ADDENDUM 2

Key to Apateticus and Allies

1. Tibia without a dorsal canal or groove; pronotum with large sharp spines on posterior lateral angle and a small thorn on posterior margin on each side of base of scutellum; osteole short, not curved; scutellum with a tumid area on each side at base (Tex.).....*Tylospilus* Stål.

— Tibia with a dorsal canal or groove bounded on each side by a slight but distinct ridge; scutellum punctate at base.....2

2. Pronotum with an acute spine on posterior margin at each side of base of scutellum.....*Apateticus* Dall.

— Pronotum without such spine.....3

3. Female with basal genital plates widely separated at base and sometimes for the entire length of their inner margins; male hypopygium with two long slender chitinized processes on each side in orifice....*Apoecilus* Stål.
— Female with basal genital plates contiguous the entire length of their inner margins; male hypopygium with a broad subtriangular or furcate chitinized plate on each side in orifice.....*Podisus* Stål.

The above groups are as easily distinguished as are most genera in Pentatomidae and ought to rank as genera.

June, 1919.

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strigipes, 201.
Podops, 171.
parvulus, 172.
Prionosoma, 180, 189.
podopioides, 189.
Proxys, 179, 189.
punctulatus, 189.

Rhacognathus, 187, 202.
americanus, 202.
Rhytidolomia, 179, 184.
belfragii, 184.

Sciocoris, 175.
microphthalmus, 175.
Scutellera aenifrons, 170
binotata, 168.
dubia, 172.
Sehirus, 203.
cinctus, 203.
Solubea, 177, 179, 188.
pugnax, 188.
Sphyrocoris, 168.
Stethaulax, 168, 170.
marmoratus, 170.

Stiretrus, 196, 197.
anchorago, var. fimbriatus, 197.
Strachia histrionica, 187.
Symphylus, 168, 171.

Tetyra, 169.
alternata, 168.
cinctipes, 172.
fimbriata, 197.
grammica, 170.
lateralis, 213.
marmorata, 170.
Thyanta, 176, 179, 184, 216.
antiguensis, 218.
brevis, 218.
calceata, 184, 217.
casta, 217.
custator, 184, 185, 217.
elegans, 217, 218.

Thyanta—*Continued*.
perditor, 217.
punctiventris, 217.
rugulosa, 217.
Thyreocoris, 207, 208.
albipennis, 209.
Trichopepla, 177, 179, 186.
atricornis, 186.
semivittata, 186.
Tylospilus, 218.

Vanduzeeina, 168.
Vulsirea, 178.

Weda, 171.

Zicrona, 197, 202.
caerulea, 202.

PLATE XVI

Wings of Pentatomoidea

Fig. 1. *Menecles insertus*, fore wing.
Fig. 2. *Tessaratoma chinensis*, the same.
Fig. 3. *Anasa tristis*, the same.
Fig. 4. *Apateticus maculiventris*, hind wing.
Fig. 5. *Homaemus proteus*, the same.
Fig. 6. *Sehirus cinctus*, the same.
Fig. 7. *Tessaratoma chinensis*, the same.
Fig. 8. *Pangaeus bilineatus*, the same.
Fig. 9. *Euschistus variolarius*, the same.
Fig. 10. *Anasa tristis*, the same.
Fig. 11. *Corimelaena pulicaria*, the same.

(Figures 1 to 11 drawn by the editor from sketches by the author; figures 12 to 77 original drawings by the editor.)

PLATE XVI

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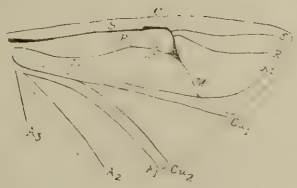
C
S
R
M
Cu1
A3
A2
A1
Cu2
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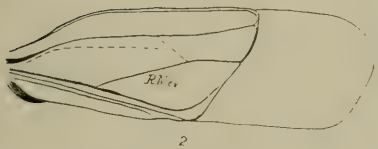
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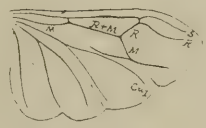
M
R+M
R
S
M
Cu1
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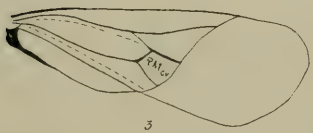
RM1v
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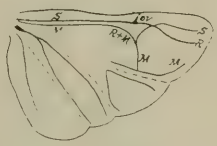
S
ov
V
R+M
S
R
M
M
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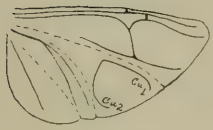
Cu1
Cu2
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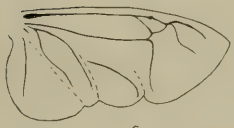
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C
S
M
V
R
M1+2
M3+4
Cu1
Cu2
A2
A1
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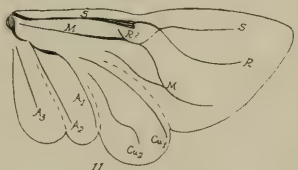
S
M
R1
S
R
M
A1
A3
A2
Cu1
Cu2
11

PLATE XVII

Details of Scutellerinae

Fig. 12. *Homaemus aenifrons*, outline of ventral plate of prothorax, one side: *e*, eye; *c*, coxa.
Fig. 13. *Homaemus parvulus*, the same.
Fig. 14. *Homaemus bijugis*, the same.
Fig. 15. *Homaemus proteus*, the same.
Fig. 16. *Stethaulax marmoratus*, outline of head, dorsal view.
Fig. 17. Symphylus sp.?, the same.
Fig. 18. *Sphyrocoris obliquus*, outline of ventral plate of prothorax, one side.
Fig. 19. *Stethaulax marmoratus*, the same.
Fig. 20. Symphylus sp.?, the same.
Fig. 21. *Stethaulax marmoratus*, osteole.
Fig. 22. Symphylus sp.?, the same.
Fig. 23. Symphylus sp.?, apex of abdomen, ventral view
Fig. 24. *Stethaulax marmoratus*, the same.

PLATE XVII

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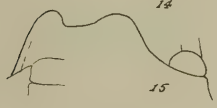

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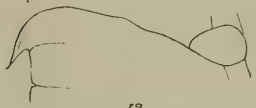

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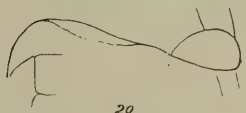

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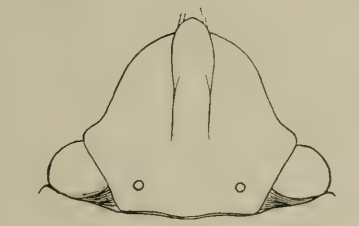

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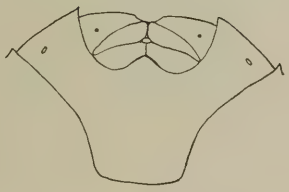

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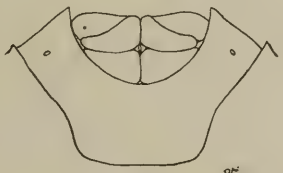

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Plate XVIII

Details of Pentatominae

Fig. 25. *Banasa dimidiata*, male hypopygium, one side, viewed from above and to one side.
Fig. 26. *Banasa calva*, the same.
Fig. 27. *Banasa imbuta*, the same.
Fig. 28. *Dendrocoris humeralis*, male hypopygium, caudal view.
Fig. 29. *Chlorochroa sayi*, left hypopygial clasper of male.
Fig. 30. *Chlorochroa uhleri*, the same.
Fig. 31. *Rhytodolomia belfragii*, the same.
Fig. 32. *Peribalus piceus*, outline of upper margin of hypopygial plate of male, one side.
Fig. 33. *Peribalus limbolarius*, the same.
Fig. 34. *Euschistus politus*, the same, and plate of upper side of hypopygial aperture from above.
Fig. 35. *Euschistus tristigmus*, the same.
Fig. 36. *Euschistus crenator*, outline of upper margin of hypopygial plate.
Fig. 37. *Euschistus impictiventris*, outline of upper margin of hypopygial plate of male, one side, and plate of upper side of hypopygial aperture from above.
Fig. 38. *Euschistus comptus*, outline of upper margin of hypopygial plate.
Fig. 39. *Euschistus conspersus*, outline of upper margin of hypopygial plate of male, one side, and plate of upper side of hypopygial aperture from above.

PLATE XVIII

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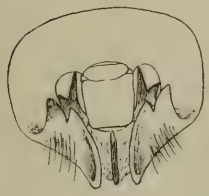

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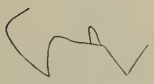

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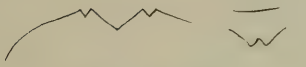

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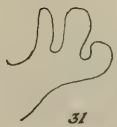

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Plate XIX

Details of Cydnidae

Fig. 40. *Galgupha atra*, arrangement of abdominal spiracles.
Fig. 41. *Corimelaena lateralis*, the same.
Fig. 42. *Cydnoides ciliatus*, the same.
Fig. 43. *Galgupha aterrima*, corium of wings.
Fig. 44. *Galgupha nitiduloides*, the same.
Fig. 45. *Galgupha nigra*, the same.
Fig. 46. *G. nitiduloides*, fore femur and tibia, front view.
Fig. 47. *G. nitiduloides*, male hypopygial plate.
Fig. 48. *G. atra*, fore femur and tibia, front view.
Fig. 49. *G. atra*, male hypopygial plate.
Fig. 50. *G. nigra*, fore femur and tibia, front view.
Fig. 51. *G. nigra*, male hypopygial plate.
Fig. 52. *G. aterrima*, fore femur and tibia, front view.
Fig. 53. *G. aterrima*, male hypopygial plate.
Fig. 54. *G. aterrima*, scutellum, lateral view.
Fig. 55. *G. nitiduloides*, the same.
Fig. 56. *Corimelaena lateralis*, corium of wings.
Fig. 57. *Galgupha atra*, the same.
Fig. 58. *Corimelaena harti*, hypopygial plate of male.
Fig. 59. *Corimelaena lateralis*, the same.
Fig. 60. *Corimelaena pulicaria*, the same.
Fig. 61. *Corimelaena montana*, the same.
Fig. 62. *Galgupha denudata*, apex of scutellum, dorsal view.
Fig. 63. *Galgupha atra*, the same.
Fig. 64. *Corimelaena lateralis*, genital plates of female, ventral view.
Fig. 65. *Corimelaena polita*, the same.
Fig. 66. *Corimelaena harti*, the same.

PLATE XIX

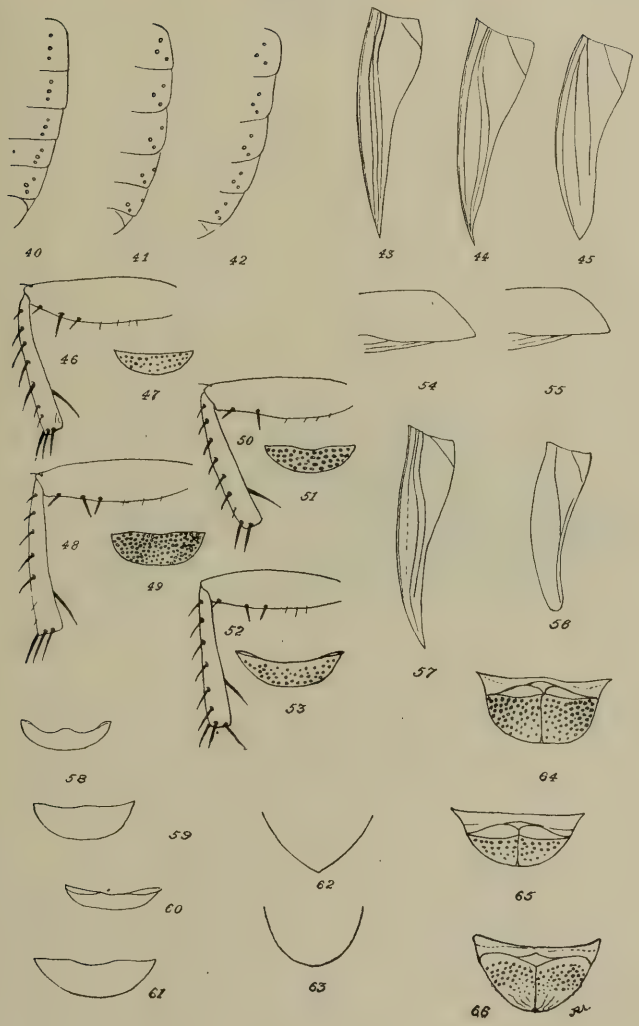
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Plate XX

Details of Thyreocorinae and Pentatominae

Fig. 67. *Corimelaena harti*, head of male, dorsal view.
Fig. 68. *C. nanella*, same as above.
Fig. 69. *Thyanta brevis*, same as above.
Fig. 70. *T. calceata*, hypopygium of male, caudal view.
Fig. 71. *T. elegans*, head of male, dorsal view.
Fig. 72. *T. punctiventris*, hypopygium of male, caudal view.
Fig. 73. *T. custator*, hypopygial clasper of male.
Fig. 74. *T. casta*, same as above.
Fig. 75. *T. custator*, hypopygium of male, caudal view.
Fig. 76. *T. elegans*, genital segment of female, ventral view.
Fig. 77. *T. elegans*, hypopygium of male, caudal view.

PLATE XX

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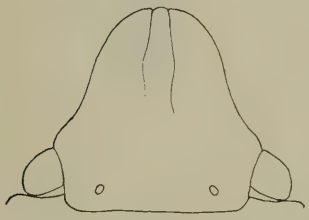

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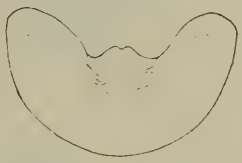

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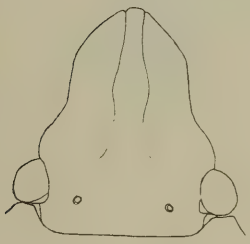

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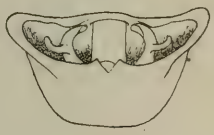

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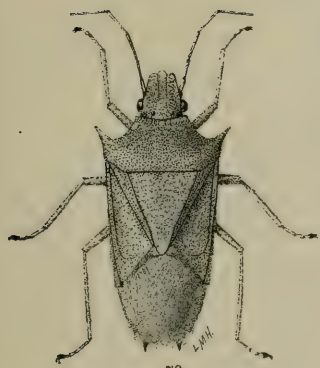
PLATE XXI

Typical Pentatomoidea

Fig. 78. *Solubea pugnax.*
Fig. 79. *Thyanta perditor.*
Fig. 80. *Chlorochroa uhleri.*
Fig. 81. *Podisus maculiventris.*
Fig. 82. *Euschistus variolarius.*
Fig. 83. *Corimelaena pulicaria.*

PLATE XXI



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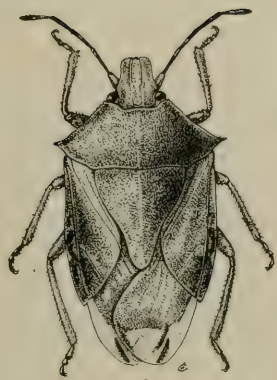

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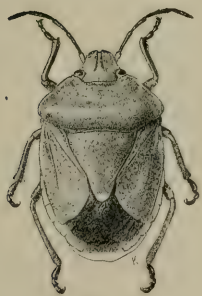

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ARTICLE VIII.—*Acanthocephala from the Illinois River, with Descriptions of Species and a Synopsis of the Family Neoechinorhynchidae.** BY H. J. VAN CLEAVE.

INTRODUCTION

There has been no published record of extensive study upon the Acanthocephala from fresh-water hosts for any part of North America. The only regional studies pursued in this country have been those of Linton (1889, 1891, 1901, and 1905) on the Acanthocephala of marine fishes, from New England southward along the Atlantic Coast. Most of the European studies aside from Zschokke's (1884), and a few others, have been compilations of host records from results of investigations in widely scattered regions. Usually these lists have ignored the geographical distribution of the parasites or have implied for them a distribution equivalent to the distribution of the hosts. Because of inaccuracies in many of the early investigations and the numerous erroneous identifications of European species these lists have comparatively little biological value.

The present paper is based upon an intensive search for Acanthocephala in the vertebrates of the Illinois River, especially in the region of Havana, Illinois. The collections were the result chiefly of work during the summer of 1910, though a number of subsequent observations have been included in the tabulated results along with a few instances of hosts examined at other points on the river, namely at Peoria and at Beardstown, Illinois.

It is especially significant that the first study of this sort should be upon forms found in the Illinois River. The life of this stream has received so much attention at the hands of Professor Forbes and his associates in the Illinois Natural History Survey that the studies relating to its life have frequently been referred to as the first significant and the most extensive of those dealing with river life. Hitherto practically no attention has been directed to the parasitic fauna of this region. The interrelationships existing between internal parasites and their hosts are of such fundamental nature that no survey of the life of any region is complete if the parasitic fauna is left out of consideration.

ACKNOWLEDGMENTS

Generous cooperation on the part of a number of individuals has enabled me to present a more complete study of fresh-water represen-

*Contributions from the Zoological Laboratory of the University of Illinois, No. 134.

tatives of this group than has ever been possible heretofore. Professor H. B. Ward has placed his collections and records from Havana, Illinois, at my disposal. Mr. R. H. Linkins has permitted the publication of two specific definitions which have previously occurred only in manuscript, concerning which a fuller statement is given later in this paper. I am especially indebted to Dr. G. R. La Rue for numerous collections of specimens including representatives of two new species. Collections of the U. S. National Museum and of the Bureau of Animal Industry, received through the courtesy of Dr. C. W. Stiles and Dr. B. H. Ransom, with the private collections of Dr. A. S. Pearse and of Dr. A. R. Cooper, have furnished an abundance of material for comparative study.

Habits of the Acanthocephala

THE LIFE CYCLE

The present paper deals with one of the most highly specialized groups of animal parsites in its relations to its hosts. The Acanthocephala are a group of worms the individuals of which reach sexual maturity in the digestive tract of various vertebrates. Life histories are not known with certainty for any of the species found in fresh-water hosts of North America, but there is no evidence that they ever lead an independent existence even for the shortest periods of time. Their development has been studied in a number of European species. In all instances it has been found that the embryos produced by the females never lose their resistant confining membranes after they are set free from the body of the definitive host until these embryos are taken into the body of the primary host. The primary host is usually an arthropod. Embryos of the Acanthocephala are taken into the digestive tract of the arthropod along with food. Here they are liberated from their confining shells and undergo further development within the body of the primary host. Intermediate hosts are not infrequent in the life cycle of the Acanthocephala. If primary hosts bearing larval Acanthocephala are eaten by an animal in which the larvae are unable to complete their development, the larvae become encysted in the tissues of the new host. The entrance into the definitive host is, in this instance, contingent upon the intermediate host's serving as food for the definitive host. The parasite never reaches sexual maturity unless the primary or intermediate host is eaten by a vertebrate in which the worm is capable of continuing its development. Thus the parasite is in every step of its development dependent upon some other organism for its maintenance. This absolute dependence of the Acanthocephala makes a study of their interrelationships with the host a topic of considerable economic importance. This is true even though the host affected may not be of direct commercial value to man. The interdependence of life in the same habitat has been so frequently emphasized that it need not be discussed fully here. One example will serve as an illustration. The gizzard-shad *(Dorosoma cepedianum)* has practically no direct commercial value, yet it serves to such great extent as food for the

most valued of fishes that any factor influencing the life and health of this shad has a distinctly economic bearing.

RELATIONS TO THE HOST

The injury inflicted upon the host by an endoparasite such as the Acanthocephala assumes several distinct aspects. Of these, three are the most readily observed: (1) mechanical injury to the host caused by the parasite; (2) physiological injury to the host through interference with the normal functioning of organs; and (3) physiological injury due to toxins produced by the parasite. For the Acanthocephala the first two of these are the most obvious. They cling to the walls of the digestive tract of the host by means of sharp spines and hooks located chiefly on a special organ of attachment called the proboscis. These hooks, in their normal functioning, pierce the wall of the intestine of the host, frequently producing thereby lacerations which are discernible as inflamed areas even on the outer surface of the intestine. Hofer (1906 :231) has called attention to the fact that with age these areas become calcified. This condition has not been observed by the present writer. In some instances—for example in members of the genus Pomphorhynchus—the intestine may be completely perforated, so that the proboscis comes to lie within the body-cavity of the host. Such perforation occasionally leads to active migration of the parasite into the body-cavity of the host.

Through lacerations and perforation of the intestinal mucosa disease-producing organisms find ready access to the tissues of the intestine, and through the body-cavity and the blood stream reach all organs of the body. Thus infection is facilitated by the presence of the Acanthocephala, while under normal conditions the unbroken lining of the digestive canal would resist the entrance of the disease-producing organisms.

Since the Acanthocephala have no trace of a digestive system they appropriate from the host intestine all of the elaborated food materials utilized in their metabolism. The effect of this loss upon the host is contingent upon the number of parasites it harbors. The writer has frequently seen fishes that were in poor flesh yield execessive numbers of Acanthocephala. There is no specific symptom, however, which will permit diagnosis of the presence of Acanthocephala by external examination of the body. Frequently the digestive tract for a considerable part of its extent becomes packed with these worms. In such quantities they effectively clog the digestive system by mechanical obstruction, and at the same time utilize such quantities of elaborated food that the supply available for the host is distinctly limited. The extent of injury to the host through toxic substances produced by these parasites has not been studied directly from either the chemical or the physiological point of view.

EXTENT OF INFESTATIONS

In the present study it has seemed inadvisable to attempt any analysis of percentages of infestation with Acanthocephala, since in many

instances the number of individuals examined for these parasites is too small to yield reliable data in this direction. One noticeable feature of the extent of infestation in this region should not be passed without comment. This is the adaptability of certain species to various hosts. It has been found that while a given species of parasite occurs in large numbers in certain host species it has been found occasionally in small numbers, frequently singly, in the intestine of different host species. This observation is especially true for the distribution of *Echinorhynchus thecatus* Linton. In a number of instances a single individual of this species has been found as a result of the examination of a fairly large number of fish of the same species, while practically every bluegill revealed a relatively large number of these worms. There are but few evidences of a fixed specificity of hosts such as are found in other parasite groups. In most instances differences in frequency of occurrence of these parasites are to be sought in differences in food habits of the hosts. Since the definitive host secures its Acanthocephala only through feeding upon the infested primary or intermediate host, the degree of infestation of the definitive host must be in some way correlated with the extent to which it preys upon the hosts of the larval parasite.

Influence of Age of Host on Infestation

Difference in degree of infestation within the same host species is frequently influenced by the age of the specimens of the host examined. The writer has frequently observed that young and very small fish may be free from acanthocephalan infestation even though the larger and presumably older specimens of the same species regularly carry parasites. The explanation of this difference has usually been sought in change of food habits by the fish at different ages. In the specimens of the gizzard-shad examined by the writer the negative records are due in many instances to periodicity in the occurrence of the species of Acanthocephala infesting this fish (Van Cleave, 1916), but it has also been observed that small individuals of this species rarely reveal an infestation. In the light of the food habits of the gizzard-shad the reverse might well be expected. The food of the young of this species, according to observations by Forbes and Richardson (1908 : 47), consists "almost wholly of small crustaceans and insect larvae" while that of larger specimens comprises "quantities of mud, with which the intestine is commonly packed from end to end, mixed with many minute plants, and much vegetable debris." The present writer has also observed that macroscopic animal forms are but rarely represented in the stomach contents of larger specimens. In spite of the fact that the young of this species feed almost exclusively on small arthropods which might serve as primary hosts of Acanthocephala, they are rarely infested, while the larger specimens, which are to a great extent vegetable and detritus feeders, usually yield large numbers of Acanthocephala.

Vertebrates Examined

The present study is limited to the parasites of three of the major groups of the Vertebrata; namely, Pisces, Amphibia, and Reptillia. No records of Acanthocephala from water-birds of the locality under consideration are available. It should be kept in mind, however, that most of our water-birds are migratory, and that consequently their parasitic fauna is not necessarily as characteristic of any restricted area as is the fauna parasitizing other fresh-water vertebrates. The writer (1918) has published the results of studies upon the Acanthocephala of birds from various parts of the United States. Little is known of the actual geographical distribution and restriction of the Acanthocephala parasitic in birds, and it is consequently unsafe to infer the presence of any given species of Acanthocephala in the Illinois River merely because it has been recorded from a species of bird whose range may include this locality. Inferences of this type have been common in the literature on parasitology, and they are responsible for many incorrect statements regarding the distribution of the parasitic fauna.

TABLE I

ASSEMBLED DATA FOR ALL SPECIES EXAMINED

PISCES *

Scientific names	Common names	Examined	Infested	Spp. of Acanthocephala found
Order Selachostomi				
Polyodon spathula (Walb.)†	Paddle-fish	1	0	
Order Rhomboganoidea				
Lepisosteus platostomus (Raf.)	Short-nosed gar	16	1	*Echinorhynchus thecatus*
L. osseus (Linn.)	Long-nosed gar	2	0	
Order Cycloganoidea				
Amia calva Linn.	Fresh-water dogfish	5	3	*E. thecatus*
Order Isospondyli				
Hiodon tergisus LeS.	Toothed herring	7	1	*E. thecatus*
Dorosoma cepedianum (LeS.)‡	Gizzard-shad	212	164	*Tanaorhamphus longirostris*
				Gracilisentis gracilisentis
Order Apodes				
Anguilla chrysypa Raf.	American eel	8	0	
Order Eventognathi				
Ictiobus urus (Agassiz)	Mongrel buffalo	1	1	*Pomphorhynchus bulbocolli*
I. bubalus (Raf.)	Small-mouth buffalo	20	5	*Echinorhynchus thecatus*
				P. bulbocolli
Carpiodes carpio (Raf.)	Common river carp	16	4	*E. thecatus*
				P. bulbocolli
				Neoechinorhynchus cylindratus
Carpiodes velifer (Raf.)	Quillback	1	0	
Erimyzon sucetta oblongus (Mitch.)	Chub-sucker	1	0	
Moxostoma aureolum (LeS.)	Red-horse	15	1	*Octospinifer macilentus*
Cyprinus carpio Linn.	European carp	1	1	*Echinorhynchus thecatus*
				Pomphorhynchus bulbocolli
Order Nematognathi				
Ictalurus punctatus (Raf.)	Channel-cat	2	1	*Echinorhynchus thecatus*
Ameiurus nebulosus (LeS.)	Speckled bullhead	3	2	*P. bulbocolli*
Ameiurus melas (Raf.)	Black bullhead	2	1	*P. bulbocolli*
Order Acanthopteri				
Pomoxis annularis Raf.	White crappie	6	4	*Echinorhynchus thecatus*
				Pomphorhynchus bulbocolli
Pomoxis sparoides (Lacép.)	Black crappie	11	7	*Echinorhynchus thecatus*
				Pomphorhynchus bulbocolli
Ambloplites rupestris (Raf.)	Rock bass	2	2	*E. thecatus*
Lepomis pallidus (Mitch.)	Bluegill	22	20	*E. thecatus*
Eupomotis gibbosus (Linn.)	Pumpkinseed	3	1	*E. thecatus*
Micropterus dolomieu Lacép.	Small-mouthed black bass	6	4	*E. thecatus*
				Neoechinorhynchus cylindratus
M. salmoides (Lacép.)	Large-mouthed black bass	1	1	*E. thecatus*
Perca flavescens (Mitch.)	Yellow perch	2	1	*E. thecatus*
Aplodinotus grunniens Raf.	Sheepshead	1	0	

REPTILIA §

Order Squamata				
Coluber constrictor Linn.	Black snake	1	0	
Order Testudinata				
Pseudemys elegans (Wied.)	Slider	22	20	*Neoechinorhynchus emydis*
P. troostii (Holbr.)		2	2	*N. emydis*
Graptemys pseudogeographica (Gray)	Map turtle	4	3	*N. emydis*
Chelydra serpentina (Linn.)	Common Snapper	2	0	
Chrysemys marginata (Agassiz)	Painted turtle	2	0	
Amyda spinifera (LeS.)	Leather-back turtle	2	0	

AMPHIBIA §

Order Salientia				
Rana pipiens Schreber	Leopard frog	21	0	
Rana catesbeiana Shaw	Bullfrog	5	0	
Bufo americanus Holbr.	Toad	7	0	

* In classification of Pisces that of Forbes and Richardson (1908) has been used.
† The single specimen of Polyodon was taken at Beardstown, Ill., in August, 1912.
‡ Examinations of Dorosoma extended over a period of several years, including all seasons of the year and several records of acanthocephalan infestation from the Illinois at Peoria.
§ Stejneger and Barbour (1917) have been followed in the classification of Reptilia and Amphibia.

Adaptability to Different Host Species

A number of interesting facts regarding specificity of hosts in fresh-water Acanthocephala may be observed in Table I. *Tanaorhamphus longirostris, Gracilisentis gracilisentis, and Octospinifer macilentus* are the only species recorded from a single host species. These all belong to the Neoechinorhynchidae. Their confinement to a single species is in sharp contrast to the adaptability displayed by *Echinorhynchus thecatus* and *Pomphorhynchus bulbocolli.* However, as *O. macilentus* is known to occur in a different species of sucker in another locality, the two species from the gizzard-shad are the only ones found in the locality under consideration which present strong evidence of restriction to a single host-species.

Members of the genus Echinorhynchus are among the commonest fish parasites, yet in the local fauna under consideration but a single species, *E. thecatus,* represents this genus. The relationship of this species to the host is obviously very generalized since it may find lodging in the bodies of fishes occupying widely different systematic positions. This species occurs not only in the more primitive orders of fish, but infests also representatives of practically every order of fish studied.

It is significant that for the region included in this survey no vertebrate host was found bearing larval Acanthocephala. Fish and amphibians frequently serve either as primary or intermediate hosts for encysted larvae which reach maturity in predaceous fish, birds, and mammals. Unfortunately, a number of species of snakes were examined before the writer began to keep negative records. The examination of snakes in other localities within the state, especially in the vicinity of Urbana, has without exception failed to reveal any Acanthocephala, either larval or adult.

In an earlier paper the writer (1915) has called attention to the infrequency of records of amphibian infestation by Acanthocephala in North America. Data in Table I are supplemented by his records of numerous examinations of both tailed and tailless Amphibia from other parts of the state, and none of these records shows acanthocephalan infestation for the amphibian fauna of the state.

Species newly credited to the Illinois River Fauna, and New Host-Records

The present study has added a number of new records concerning the distribution of Acanthocephala, the following four species being reported for the first time from Illinois: *Echinorhynchus thecatus* Linton (1891), *Neoechinorhynchus cylindratus* (Van Cleave, 1913), *Pomphorhynchus bulbocolli* Linkins, n. sp., and *Octospinifer macilentus,* n. sp.

For *E. thecatus,* twelve additional hosts are added; namely, *Lepisosteus platostomus, Hiodon tergisus, Ictiobus bubalus, Carpiodes carpio, Cyprinus carpio, Ictalurus punctatus, Pomoxis annularis, P. sparoides,*

Lepomis pallidus, Eupomotis gibbosus, Micropterus salmoides, and *Perca flavescens.*

For *N. cylindratus* two new host species are reported: *Carpiodes carpio* and *Micropterus dolomieu.*

Comparison with other Regional Studies

In his report on "Fish Entozoa from Yellowstone National Park" Linton (1893 : 555) listed but two species of Acanthocephala. They were given names of European species, though recent investigation has shown that extremely few species of fresh-water Acanthocephala are common to Europe and North America. Drawings and descriptions show that one species is of the genus Echinorhynchus and that the other is one of the Neoechinorhynchidae, though data are insufficient for the determination of species. This report by Linton constitutes as thorough a study of Acanthocephala as has been made for any fresh-water habitat in North America up to the present time; there is, consequently little data with which to compare the results of the present study; and, as indicated on an earlier page, there are few valuable European contributions with which comparison may be made.

Zschokke (1884) made an intensive study of the parasites from twelve of the most common species of fresh-water fishes from Lake Geneva, in Switzerland. In all, he examined over four hundred individuals, which yielded but three species of Acanthocephala; namely, *Acanthocephalus lucii (= Echinorhynchus angustatus), Pomphorhynchus laevis (= E. proteus),* and *Neoechinorhynchus rutili (= E. clavaeceps).* Eight of the twelve species of fish studied were parasitized with Acanthocephala. In the locality examined by Zschokke the number of species of Acanthocephala is evidently very low when compared with the number of species found in the Illinois River. The genus Acanthocephalus, found in the European fishes, is wanting in the Illinois River fauna, while four genera of Neoechinorhynchidae occur in the Illinois River fish as against a single species revealed by Zschokke's study.

Lühe's check-list of parasites of European fresh-water hosts (1911) includes eight valid species of Acanthocephala characteristic of the fresh-water fishes of Europe. One additional species, *E. gadi,* is found in marine and migratory fishes, and is consequently taken into fresh-water habitats by the migratory fishes though not strictly characteristic of that habitat. Since Lühe in his list assembled the data concerning all known European fresh-water hosts, a comparison of his record with that for the Illinois River alone would be wholly inadequate; the writer has consequently included in Table II data for all fresh-water species of Acanthocephala known to belong to the North American fauna. The writer has previously (1915) discussed the difference in numbers of species of Acanthocephala infesting Amphibia on the two continents.

TABLE II

SPECIES OF ACANTHOCEPHALA REPRESENTED IN EUROPEAN AND NORTH AMERICAN FRESH-WATER HOSTS EXCLUSIVE OF BIRDS

Genera of Acanthocephala	Species found in European hosts (Lühe, 1911)	Species in Illinois River hosts	Species known to occur in North America
	PISCES		
Echinorhynchus	*truttae*	*thecatus*	*coregoni*
	salmonis		*salvelini*
	clavula		*gadi (?)*
	gadi (?)		*thecatus*
Pomphorhynchus	*laevis*	*bulbocolli*	*bulbocolli*
Acanthocephalus	*anguillae*		
	lucii		
Rhadinorhynchus	*pristis*		*tenuicornis?*
Neoechinorhynchus	*rutili*	*cylindratus*	*cylindratus*
			tenellus
			crassus
Tanaorhamphus		*longirostris*	*longirostris*
Octospinifer		*macilentus*	*macilentus*
Gracilisentis		*gracilisentis*	*gracilisentis*
	AMPHIBIA		
Acanthocephalus	*falcatus*		*ranae*
	ranae		
	anthuris		
	REPTILIA		
Neoechinorhynchus	*rutili (?)*	*emydis*	*emydis*

SYSTEMATIC CONSIDERATION OF SPECIES

So little has been written concerning the Acanthocephala of American fresh-water hosts that it seems desirable to bring together the scattered descriptions of the known species and to add to these the descriptions of a number of new species. This seems especially desirable in order that those interested in the study of economic problems, especially those connected with the fisheries industry, may have a ready means of identifying species in this important group of fish parasites. The older literature, even within its limited scope, does not meet this demand because of the failure of the earlier workers to recognize the distinctness of North American Acanthocephala from the Acanthocephala found on the Europeon continent. Again, many erroneous identifiications of species have apparently extended the range of distribution for known forms owing to the inadequate available descriptions of the species reported upon. In the following section descriptions are given for the genera and species of Acantho-

cephala infesting fresh-water hosts of North America exclusive of the birds.

LINKINS' MANUSCRIPT SPECIES

In a manuscript thesis filed in the library of the University of Illinois, Mr. Ralph H. Linkins described two new species of Acanthocephala belonging to the genus Echinorhynchus. In the course of later study he described in manuscript another new species, belonging to the genus Pomphorhynchus. One of the species of Echinorhynchus, *E. salvelini* Linkins, was subsequently cited and described by Professor H. B. Ward (Ward and Whipple, 1918), under whose direction the thesis investigation was being conducted. Owing to his entering the Army, Mr. Linkins has been unable to put the results of his investigation into form for publication, and he has kindly granted the writer permission to quote from the manuscript descriptions in order that the species may be definitely cited in connection with the present work. The specific definitions of *Echinorhynchus coregoni* and *Pomphorhynchus bulbocolli* are entirely the result of work done by Mr. Linkins, to whom the writer wishes to give full credit.

Family ECHINORHYNCHIDAE

The family Echinorhynchidae was created by Hamann (1892) to include all of the Acanthocephala not set off in his other two families, Gigantorhynchidae and Neoechinorhynchidae. The species included in this heterogeneous group were, until a few years ago, all embraced in the one genus Echinorhynchus. Comparatively recent work, dating from the studies of Monticelli and of Lühe, has resulted in the erection of numerous genera from the disrupted genus Echinorhynchus. All of these genera, with the exception of those included in the Centrorhynchidae, are still retained in the family Echinorhynchidae. More thorough study of this unnatural assemblage of genera will probably lead either to the establishing of several families or, at least, to the recognition of subfamily groups within it. As the family now stands, little would be gained by an attempt to describe it, for there are very few characters common to all of the genera. Four genera usually assigned to this family are represented in the fresh-water fauna of North America. Each of these genera with its included species will be treated separately.

Echinorhynchus Zoega, 1776

Generic Diagnosis.—Acanthocephala of small to medium size, parasitic as adults in the alimentary canal of fish. Subcuticula and lemnisci provided with numerous small nuclei or with a few very large finely dendritic nuclei. Body proper and neck spineless. Proboscis long, approximately cylindrical, armed with circles of hooks which are alternate in arrangement. Hooks of practically uniform size except those of a few basal circles, which are much reduced. Proboscis receptacle composed of

two layers of muscle inserted at the base of the proboscis. Central nervous-system near the middle of the proboscis receptacle.

Echinorhynchus thecatus Linton, 1891

(Pl. XXII, Fig. 1–4)

Length: females, 11 to 26 mm.; males, 7 to 12 mm. In fully extended individuals both ends of the body are bent toward the ventral surface. Proboscis, when fully extended, frequently takes a position perpendicular to the axis of the body; in case of extreme extrusion may form acute angle with main axis of body. Proboscis usually about 1 mm. long. Neck about one-fourth the length of proboscis. Proboscis receptacle long and slender, about 1.5 times the length of proboscis. Central nervous-system located near the center of the proboscis-receptacle. Hooks alternate in arrangement; restricted entirely to proboscis; arranged in twelve longitudinal rows of twelve to thirteen hooks each. Lemnisci long and slender, about 1.5 times the length of proboscis-receptacle. Embryos within body-cavity of gravid female 80 to 110 μ long by 24 to 30 μ wide. The hooks at the base of the proboscis are 41 to 53 μ long, nearly straight, and in many instances each hook is completely ensheathed in a cuticular collar (Fig. 2). Near the middle of the proboscis, hooks of a much heavier form occur. These are rather uniformly about 71 μ long, although those on the ventral surface of the proboscis are more strongly curved and a little heavier than those on the dorsal (Fig. 2, 4). Hooks near the anterior tip are not so much recurved and not so strong as those near the middle though they reach greater length; namely, 77 to 89 μ. In the male eight cement glands are closely compacted at the posterior border of the hind testis.

Graybill (1902 : 197) has given a very good description of this species, from which the foregoing data vary but slightly.

Hosts: *Morone americana, Roccus americanus, Micropterus dolomieu, M. salmoides, Ambloplites rupestris, Amia calva, Lepisosteus platostomus, Hiodon tergisus, Ictiobus bubalus, Carpiodes carpio, Cyprinus carpio, Ictalurus punctatus, Pomoxis annularis, P. sparoides, Lepomis pallidus, Eupomotis gibbosus, Perca flavescens.*

Echinorhynchus salvelini Linkins, 1918 (in Ward and Whipple)

(Pl. XXIII, XXIV, Fig. 5, 10, 12)

Body slightly enlarged anteriorly. Males 7 to 9 mm. long; 0.82 to 1.27 mm. in maximum diameter. Females 10 to 17 mm. long; 1.2 to 1.6 mm. in maximum diameter. Proboscis cylindrical, armed with 16 longitudinal rows of about 13 hooks each. Basal hooks 39 to 50 μ long. Hooks on middle and anterior proboscis-regions 44 to 68 μ long, with basal process 83 μ long. Embryos 115 to 165 μ long by 20 to 25 μ broad; middle

shell of embryos forming polar prolongations which are more than twice as long as they are wide.

Host, *Cristivomer namaycush* (Walbaum), the great lake trout.

Echinorhynchus coregoni Linkins, n. sp.

(Pl. XXIII, XXIV, Fig. 6, 11, 13)

"Body enlarged at anterior end. Males 3 to 3.7 mm. long, maximum width 0.8 to 1.05 mm., at anterior one-fourth of body. Females 3 to 5.5 mm. long; widest part of body 0.6 to 1.5 mm. Proboscis cylindrical, carrying twenty circular rows of hooks, each circle containing six hooks. Hooks of adjacent rows alternate. Basal hooks 28 to 53 μ in length. Hooks in middle region of proboscis 65 to 80 μ in length. Terminal hooks smaller than those of middle rows. Ventral hooks larger and stronger than dorsal hooks. Embryos vary from 51 to 91 μ in length and from 17 to 20 μ in width. The common size is 77 by 19 μ."

As indicated in an earlier part of this paper the above description is quoted directly from a manuscript thesis by Linkins.

Host, *Coregonus clupeiformis*.

Pomphorhynchus Monticelli, 1905; emended by Porta, 1907

Monticelli (1905 : 11) named the genus Pomphorhynchus in a footnote, without citing for it any type or characteristic species. Furthermore, he did not, in his definition, differentiate the genus, as later emended by Porta, (1907), from the genus Filicollis. Porta (1907 : 413) assigned *Echinorhynchus proteus* to the genus Pomphorhynchus, and since *P. proteus* is a synonym of *P. laevis*, the latter becomes the type of the genus.

There are numerous early records of the occurrence of *"E. proteus"* in North American fishes, but without much question they are all based upon misidentification of the species. The writer has examined numerous specimens from American hosts and has never found one which agreed with the detailed descriptions of the European species. All the examples of this genus that have come to the attention of the writer clearly belong to a new species, to which the manuscript name *Pomphorhynchus bulbocolli* has been assigned by Linkins. Linkins' description follows the generic diagnosis.

Generic Diagnosis.—Acanthocephala parasitic as adults in the alimentary canal of fish. Body unarmed. Neck very long, cylindrical except at its anterior extremity, where it expands into an approximately spherical bulla. The proboscis extends as an approximately cylindrical structure from the anterior region of this neck-enlargement. Tip of proboscis somewhat reduced in size. Proboscis receptacle inserted at the base of the proboscis, extending posteriorly through the neck, as a double-walled sac, into the anterior portion of the body-cavity proper. Central nervous-system at the posterior end of the proboscis-receptacle.

Pomphorhynchus bulbocolli Linkins, n. sp.

(Pl. XXIII, Fig. 7, 8)

Body elongate, tapering toward the posterior end. Neck prominent, measuring 2.6 to 4 mm. in length; diameter 0.15 to 0.4 mm. in posterior portion and 0.8 to 1.5 mm. in region of spherical enlargement. Proboscis cylindrical, 0.5 to 0.6 mm. long by 0.07 to 0.2 mm. wide; armed with twenty-four to twenty-eight circular rows of hooks. Basal circle with twelve hooks; remaining circles with six hooks each; hooks in circles anterior to basal circle alternating. Smallest hooks at tip of proboscis, about 16 μ long, with a diameter of 4 μ. Largest hooks, in seventh or eighth circle from tip, 36 to 40 μ long with a diameter of 22 μ. Hooks posterior to the eighth row 20 to 36 μ long with a diameter of 4 to 8 μ. Roots on hooks of first eight circles back from tip of proboscis 10 to 40 μ long. Embryos within body-cavity of gravid females 53 to 83 μ long by 8 to 13 μ in diameter; commonest size 63 by 10 μ.

Hosts: *Ictiobus urus, I. bubalus, Carpiodes carpio, Cyprinus carpio, Ameiurus nebulosus, A. melas, Pomoxis annularis,* and *P. sparoides.* Intestine infested.

Rhadinorhynchus Lühe, 1911

Generic Diagnosis.—Acanthocephala parasitic as adults in the intestine of fish. Anterior body-region armed with scattered cuticular spines, ensheathed by cuticular folds. Proboscis and proboscis receptacle very long. Ventral proboscis-hooks stronger than dorsal. Proboscis receptacle a two-walled muscular sac with the brain located near its middle. Lemnisci long, finger-like.

This genus is not strongly represented in American hosts either from the point of view of species or of numbers of individuals encountered in the examination of fishes. It is typically a marine genus which is probably occasionally brought into fresh-water by migratory fishes.

Rhadinorhynchus ornatus Van Cleave, 1918

Proboscis armed with from twenty-two to twenty-four longitudinal rows of about forty hooks each. Hooks on proboscis 50 to 80 μ long. Anterior body-region armed with scattered cuticular spines about 80 μ long. Embryos about 60 μ long.

Hosts, marine and migratory fishes.

Rhadinorhynchus tenuicornis Van Cleave, 1918

(Pl. XXIII, Fig. 9)

Proboscis armed with ten to fourteen longitudinal rows of approximately twenty-six hooks each. Proboscis hooks of female 40 to 80 μ long; those of male, near base, may be as short as 20 μ. Conspicuous crescent of about seven long spines on the ventral surface of the proboscis-

region at the division between neck and proboscis. Body spines of female 60 to 80 μ in length; those of male about 28 μ. Embryos within body-cavity of gravid females 60 to 80 μ long and 12 μ in diameter, with middle membrane drawn out into attenuated polar capsules.

Hosts: marine fishes, and "trout" from Baltimore—uncertain as to whether marine or fresh-water trout.

Acanthocephalus Koelreuter, 1771

Generic Diagnosis.—Acanthocephala of small to medium size, parasitic as adults in the alimentary canal of fishes and amphibians. Subcuticula and lemnisci provided with numerous small nuclei. Proboscis ovate or a short cylinder. Body proper and neck spineless. Proboscis receptacle a two-walled muscular sac inserted at the junction of proboscis and neck. Central nervous-system located at posterior extremity of proboscis-receptacle.

A single instance of the occurrence of specimens belonging to this genus is on record (Van Cleave, 1915) for the American continent. The specimens examined, agree in all essential details with the European *A. ranae,* and have been identified as such by the writer.

Acanthocephalus ranae (Schrank, 1788)

Proboscis short, slightly larger in the middle than at extremities; armed with twelve to twenty longitudinal rows of four to seven hooks each. Largest hooks, near the middle of the proboscis, 77 to 80 μ long; hooks at anterior tip of proboscis about 60 μ long; those in basal row 30 to 50 μ. Embryos within body-cavity of gravid female about 110 μ long by 13 μ in diameter.

Host, *Diemyctylus viridescens* Raf.; Franklin Falls, Baltimore, Maryland.

Family NEOECHINORHYNCHIDAE

Distribution and Diversification of Species

The Neoechinorhynchidae occur as adults chiefly in the intestine of fishes, though one North American species is restricted to the intestine of turtles. Hitherto only seven species have been considered as validly placed in this family. Of these, two occur in European hosts, while five, according to present records, are confined to the American continent. Recently, in examining the collections of Dr. G. R. La Rue taken from Douglas Lake, Michigan, the writer discovered an abundance of well-preserved material representing two new species of Neoechinorhynchidae, one of which clearly belongs to a new genus. Thus, with seven North American species, the family seems to have attained a much higher degree of differentiation on this continent than it has in Europe. This is evidenced not only by the greater number of species in the less thoroughly studied

American hosts, but even more strikingly in the greater diversification of structure among the American species.

Hamann's description of the Neoechinorhynchidae (1892), based upon a knowledge of but one genus comprising two species of monotonous similarity, quite naturally emphasized for the family those characters which had been selected to characterize his Neorhynchus. The discovery of more strikingly diversified American species led the present writer (1913) to emend the generic diagnosis in order that *N. gracilisentis* and *N. longirostris* might be included within the genus Neoechinorhynchus (= Neorhynchus). However, more recent study has shown that the differences between these two species and the other members of the genus are too great to be regarded as of merely specific value. In the description of *N. longirostris* (Van C.) the writer (1913 : 182) pointed out the possibility of establishing a new genus for this species, but because of a few fundamental points of similarity in body-structure between this and other members of the family it was placed in the genus Neoechinorhynchus. Recent further study of Neoechinorhynchidae, made possible by the addition of newly discovered species, and a re-study of cotypes of *N. longirostris* have convinced the writer that the arguments originally advanced for retaining this species within the genus apply more strictly as reasons for its retention within the family. The validity of this position was seen by Professor Henry B. Ward who (1918:547) erected for it a new genus, Tanaorhamphus, with *N. longirostris* (Van C.) as type.

Inasmuch as the species *N. gracilisentis* (Van C.) possesses characters which give strong evidence of its generic isolation it becomes advisable to create for it a new genus, for which the writer proposes the name Gracilisentis, *Neoechinorhynchus gracilisentis* becoming the type of the genus.

With the accumulation of new information and new interpretations of facts regarding members of this family more definite consideration should be given to the characterization of the family and of its constituent genera. In the following synopsis the writer has endeavored to describe the family and its genera in a more complete manner than has been attempted heretofore.

Family Characters

Acanthocephala of small to medium size, parasitic as adults in the alimentary canal of fishes and reptiles. Wall of proboscis-receptacle a single layer of muscle. Brain near base of proboscis-receptacle. Body devoid of spines; spines or hooks on proboscis only. Nuclei of subcuticula and of lemnisci extremely large, normally of fixed number and definite arrangement; the subcuticula with five in mid-dorsal line of body and one in mid-ventral line near anterior end; the lemnisci normally with two in one lemniscus and a single nucleus in the other. Embryos borne inside body of females provided with three membranes. Membranes in all known species fully concentric, without polar modifications or constric-

tions. Testes elliptical, usually contiguous. Cement gland a single syncytial mass containing relatively few giant nuclei.

The giant nuclei furnish the most easily available characters for the recognition of members of this family. Subcuticular nuclei in members of the other families of Acanthocephala show a considerable degree of variability in size and in form, but in no case do they approach the condition found in this family. The dendritic nuclei of *Echinorhynchus thecatus* Linton are relatively difficult to demonstrate. In addition they differ so broadly from the form of the giant nuclei of the Neoechinorhynchidae that no confusion of the two is possible. The subcuticular nuclei are especially conspicuous in the Neoechinorhynchidae. Their location is clearly discernible as pronounced elevations of the body-surface both in living individuals and in preserved specimens even before staining. The number found in the subcuticula so far has been absolutely constant for every individual of the family examined, but their relative position within the dorsal and ventral lines of the body is subject to slight individual variability even within the confines of a given species. For example, the single nucleus of the mid-ventral line does not always bear a fixed relationship to the nuclei of the mid-dorsal line, but may be directly opposite the second dorsal nucleus or slightly anterior or posterior to it. The ratio of the spacing between the dorsal nuclei and the body-length is apparently an inconstant one.

The giant nuclei of the lemnisci are apparently constant both in number and in arrangement for all members of the family. In the examination of several hundred individuals, representing all the different genera, in every instance where conditions permitted close observation one lemniscus showed two giant nuclei while the other bore but a single one.

The cement gland of Neoechinorhynchidae shows considerable variation in the number of giant nuclei even within the confines of a single genus; but within species limits the number of nuclei in this gland is absolutely fixed. Bieler has found eight in the cement gland of *N. agilis* and twelve in that of *N. rutili*. As to Amercian species of Neoechinorhynchus, the writer has found eight giant nuclei in the cement gland of *N. cylindratus*, of *N. emydis*, of *N. tenellus*, and of *N. crassus*. In *Tanaorhamphus longirostris* there are sixteen giant nuclei in the cement gland, while in Gracilisentis and in Octospinifer there are only eight.

The shape of the proboscis and the shape and number of the proboscis-hooks and their roots afford the most readily available characters for the separation of the genera of this family.

Synopsis of North American Genera and Species

Neoechinorhynchus Stiles and Hassall, 1905, *sens. str.*

Neorhynchus Hamann, 1892, preoccupied.

Eorhynchus Van Cleave, 1914.

Echinorhynchus Zoega, 1776, in part.

Generic Diagnosis.—Neoechinorhynchidae with short, globose proboscis armed with three circles of six hooks each. Terminal hooks con-

spicuously larger and heavier than those of remaining rows, and the only ones which bear conspicuous reflexed root-processes. Each root a broad, flattened disc, pyriform in surface view, usually approximately parallel to surface of proboscis wall. The thorn or hook proper attached at the apical or anterior end of the root, and appreciably longer than the root.

Of this genus three previously described and one new species are found in North American hosts.

Neoechinorhynchus cylindratus (Van Cleave, 1913)

(Pl. XXIV, XXV, Fig. 15, 17, 18)

Bodies large, almost cylindrical except in young forms, in which the posterior part is gradually narrowed. Females 10 to 15 mm. long, with a maximum diameter of 0.7 mm. a short distance back of the proboscis. Males 4.5 to 8.5 mm. long, with a diameter of 0.5 to 0.7 mm. Proboscis slightly broader than long (0.172 by 0.150 mm.). Hooks of terminal circle 79 to 97 μ long, 14 μ thick at base, each bearing a root 58 μ long and 29 μ broad. Hooks of middle row 37 μ long and 5 μ through at base. Basal hooks 21 to 25 μ long and 3 μ through at base. Embryos inside body of gravid female 49 to 51 μ long and 15 to 21 μ broad.

Type host, *Micropterus salmoides;* type locality, Pelican Lake, Minnesota.

Additional hosts: *Anguilla chrysypa, Micropterus dolomieu, Carpiodes carpio.*

Neoechinorhynchus tenellus (Van Cleave, 1913)

(Pl. XXIV, XXV, Fig. 16, 19, 20)

Bodies small, attenuated. Females 3.5 to 13 mm. long; 0.6 mm. in maximum diameter. Males 2 to 8 mm. long. Proboscis nearly cylindrical, 0.15 mm. long by 0.135 mm. wide. Hooks of anterior circle 90 to 110 μ long; those of middle circle 38 μ; those of basal circle about 27 μ. Embryos 37 to 45 μ long by 12 to 16 μ broad.

Hosts: *Esox lucius, Stizostedion vitreum.*

Neoechinorhynchus emydis (Leidy, 1852)

(Pl. XXIV, XXV, Fig. 14, 21, 22, 23)

Parasitic as adults in alimentary canal of turtles. Body much elongated, approximately cylindrical. Females 10 to 32 mm. long with average width of 0.7 mm. Males about 8 to 11 mm. long by 0.7 mm. wide. Proboscis globular, length usually equaling breadth; average length 0.18 mm. Terminal hooks 95 to 103 μ long, points usually reaching beyond bases of hooks of middle circle. Hooks of middle circle 49 to 59 μ long; those of basal circle 35 to 54 μ. Embryos within body cavity of gravid female oval, 16 by 11 μ.

Hosts: *Graptemys geographica, G. pseudogeographica, Clemmys insculpta, C. guttata, "Emys serrata," Pseudemys elegans, P. troostii, P. scripta, P. concinna.*

Neoechinorhynchus crassus, n. sp.

(Pl. XXVI, Fig. 24, 25, 28)

Body short and thick, almost cylindrical, tapering but slightly toward either extremity. Observed males 4 to 7 mm. long; females 6 to 9 mm. Maximum diameter of body usually in region of second dorsal subcuticular nucleus, just behind the single mid-ventral nucleus; in males usually slightly more than one-tenth of the total body-length, in females slightly less than one-tenth of the same. Body wall, especially the subcuticula, very thick, usually from 80 to 100 μ except in certain regions in anterior part of body of gravid females, where it becomes considerably thinner, frequently reaching only about 60 μ. Proboscis 0.27 to 0.325 mm. long and 0.24 to 0.27 mm. in diameter. Armed with three circles of six hooks each. Hooks of terminal circle only provided with prominent roots. Terminal hooks 94 to 100 μ long; hooks of middle circle 71 to 83 μ; those of basal circle 47 to 71 μ. Proboscis receptacle typical of the genus in shape and structure; 0.45 to 0.6 mm. in length. Testes in largest males approximately the same size, 0.87 by 0.38 mm.; in broad contact with each other. In smaller males the anterior testis is the larger. Cement gland, in structure, typical of that described for the family; crowded into hind margin of posterior testis; approximately the same size as posterior testis except in largest specimens, in which it reaches 1.25 by 0.4 mm.; contains eight giant nuclei. Hard-shelled embryos within body of gravid female 35 by 14 μ.

Cotypes in collection of U. S. National Museum and in collections of G. R. La Rue and of H. J. Van Cleave.

Host, *Catostomus commersonii* (Lacép.).

Type locality, Douglas Lake, Michigan.

This species in many respects resembles the greatly variable Mediterranean species, *N. agilis*. The two species are, however, easily separated on the basis of general appearance even though the measurements and data usually given in specific definitions do closely agree. Biological evidence and morphological data taken together, give sufficient grounds for the ready differentiation of the two species. There is fairly strong evidence that *N. agilis* does not occur outside the Mediterranean, where it is found in fishes of the genus Mugil. Though fishes of this genus occur on the Atlantic coast of North America they have never been found to harbor any Acanthocephala. It seems improbable that a given species of Acanthocephala, *N. agilis*, for example, could have been brought to this continent by a marine fish and become established in an inland lake, leaving no trace of its transition from a marine to a fresh-water form. Numerous minor differences in structure give sufficient evidence of the distinctness of the two species even though ranges of variability in measurements for the two species frequently overlap. In general body-shape *N. crassus* is nearly cylindrical with a sudden diminution in size at each extremity, while *N. agilis* shows a conspicuous gradual tapering in both directions from the region of maximum diameter. The posterior two

thirds of the body of *N. agilis* tapers, while only the tip of the body of *N. crassus* is conical.

The body of *N. crassus* is much more robust than that of *N. agilis*. This appearance is due primarily to the greater thickness of the body-wall in *crassus*. In the region of maximum diameter of the body the wall of *N. crassus* rarely measures less than 80 μ, and is frequently 100 μ thick, while in *N. agilis* the body wall in the same region rarely reaches a thickness greater than 40 μ. This same difference may be expressed in the ratio between the thickness of the body-wall and the diameter of the body-cavity. In *N. crassus* the maximum diameter of the body-cavity is not more than eight times the thickness of the body-wall, while it is usually only about five times the thickness of the wall. In specimens of *N. agilis* studied by the writer the maximum diameter of the body-cavity is frequently eighteen or twenty times the thickness of the body-wall.

The proboscis of *N. crassus* is conspicuously larger than that of *N. agilis*.

The male reproductive organs in *N. agilis* are usually located farther from the posterior tip of the body than in *N. crassus*, and therefore the ducts leading from the cement gland and from the testes are longer in the former than in the latter.

The cotypes upon which the description of *N. crassus* is based were collected by Dr. George R. La Rue from the intestine of the common sucker, at Douglas Lake, Michigan, July 20, 1912.

Octospinifer, n. gen.

Generic Diagnosis.—Proboscis short, globose, usually slightly broader than long; provided with three circles of eight hooks each. Hooks of terminal circle not much larger or stronger than hooks of middle circle and but little longer than the root process. Testes elliptical, in contact with each other but not joined by a broad contact-surface. Cement gland not in direct contact with posterior testis. The two lemnisci dissimilar in nuclear content, one possessing two giant nuclei and the other a single one. Central nervous-system located at one side of the proboscis-receptacle, near its base.

Type species, *Octospinifer macilentus*.

Octospinifer macilentus, n. sp.

(Pl. XXVI, Fig. 26, 27, 29)

Body long, approximately cylindrical, tapering slightly toward posterior extremity. Males about 4 mm. long. Females about 10 mm. long; maximum diameter about 0.4 mm., although in some gravid females it is as great as 0.58 mm. Genital opening of female on ventral surface about 0.1 mm. from the posterior extremity of the body. Posterior extremity of body about 0.19 mm. in diameter. Proboscis short, globular, usually slightly broader than long; length about 0.106 mm., diameter about 0.120 mm. The eight hooks of terminal circle equal in size; not conspicuously

larger than hooks of remaining circles. Terminal hooks 41 μ long; hooks of middle circle 32 to 35 μ; those of basal circle 24 to 30 μ. Testes elliptical, not crowded together. Sperm ducts of mature males frequently showing a number of vesicular enlargements between the posterior margin of anterior testis and the anterior margin of the cement-gland. Cement gland not in close contact with posterior testis, frequently broadly separated from it; form typical of the family, containing eight giant nuclei. Embryos within body-cavity of mature females 30 to 47 μ long by 15 to 18 μ wide.

Type host, *Catostomus commersonii* (Lacép.); type locality, Douglas Lake, Michigan.

Cotypes deposited in the U. S. National Museum and in the collections of G. R. La Rue and of H. J. Van Cleave. The material from which this species was described was collected by Dr. George R. La Rue in July and August, 1912.

Gracilisentis, n. gen.

Neoechinorhynchus, in part; (= Neorhynchus = Eorhynchus).

Generic Diagnosis.—Neoechinorhynchidae of small size, parasitic in the digestive tract of fishes. Body proper unarmed. Proboscis provided with three circles of twelve hooks each. Each thorn ensheathed in a prominent cuticular collar which permits only a small portion of the thorn to protrude from the surface of the proboscis. Each hook of the terminal circle provided with a conspicuous root-process several times longer than the exposed portion of the spine. Root composed of a broad flat basal area which, by gradual diminution in size anteriorly, makes an ill-defined transition from thorn to root. Basal region of terminal roots frequently slightly indented. Hooks of middle circle similar in general form to those of terminal circle except that root processes are shorter and less easily observed. Basal hooks without recurved roots.

Type species, *Gracilisentis gracilisentis* (Van Cleave, 1913).

Gracilisentis gracilisentis (Van Cleave, 1913)

(Pl. XXVII, Fig. 30, 31, 32)

Body small, tapering slightly at either extremity; extremities bent toward ventral surface, forming a slight crescent. Fully mature females 1.7 to 4 mm. long, greatest diameter slightly anterior to middle of body, 0.38 mm. Males 1.5 to 3 mm. long, greatest diameter 0.3 mm. Proboscis approximately pear-shaped, usually with a slight constriction between the middle and basal circles of hooks. All hooks very delicate; those of terminal circle 15 to 17 μ long, with a root 20 μ; those of second circle 12 to 15 μ, with root about 15 μ long; those of basal circle almost straight, 15 to 20 μ long, without root. Cement gland containing eight giant nuclei. Embryos conspicuously spindle-shaped 36 to 40 μ long by 10 μ broad.

Type host, *Dorosoma cepedianum* (LeS.); type locality, Illinois River at Havana, Illinois.

Tanaorhamphus Ward, 1918

Neoechinorhynchus, in part; (= Neorhynchus = Eorhynchus).

Generic Diagnosis.—Neoechinorhynchidae of small to medium size, with cylindrical proboscis several times longer than wide. Proboscis armed with about sixteen longitudinal rows of hooks. Rows frequently incomplete and imperfect. Cement gland of type characteristic of the family.

Type species, *Tanaorhamphus longirostris* (Van Cleave, 1913).

Tanaorhamphus longirostris (Van Cleave, 1913)

(Pl. XXVII, Fig. 33, 34, 35)

***Neoechinorhynchus longirostris* (Van Cleave, 1913).**

Body robust, with posterior extremity slightly flexed ventrad. Proboscis when fully extended inclined toward ventral surface at conspicuous angle. Females average about 6 mm. in length and have a diameter of about 0.63 mm. Males average 4 mm. in length and have a maximum diameter of 0.47 mm. Proboscis cylindrical, 0.5 mm. long, and with a diameter of 0.15 mm. Hooks rather irregularly arranged in about sixteen to twenty longitudinal rows with about ten hooks in each row. Largest hooks near anterior end of proboscis, about 54 μ long. A few hooks near the base of the proboscis about 16 μ long. Cement gland with sixteen giant nuclei. Embryos within body-cavity of gravid female 27 μ in length by 8 to 10 μ in diameter.

Type host, *Dorosoma cepedianum* (LeS.) ; type locality, Illinois River at Havana, Illinois.

European Species

reexamination of the types of *N. agilis* (Rudolphi)

European representatives of the genus Neoechinorhynchus have been characterized by European parasitologists in widely different descriptions. Attempting to use these definitions of species in studying members of the same genus from North American hosts, the present writer found the characterizations so diverse that it was difficult to determine whether the conflicting data represented individual variability within the species or resulted from inaccurate observations and erroneous identification. The records of each of a number of the investigators are so inconsistent that tabulated comparisons of the data when considered alone afford practically no key to the solution of the problems of specific identity. Fortunately, through the efforts of Professor Henry B. Ward, the writer, in 1913, had the rare good fortune to secure from the Berlin Museum, for examination, two "type" specimens of *N. agilis* (Rudolphi). A comparison of these with the descriptions of European investigators and with other specimens from European hosts constitutes the basis of the discussion which follows.

Rudolphi's description of *N. agilis (= Echinorhynchus agilis)* was based upon an examination of nine individuals taken from the intestine of *Mugil cephalus* at Spezia. The above-mentioned alcoholics from the Berlin Museum (Catalog No. 1179) had in the vial with them a label indicating that they were "types" of *Echinorhynchus agilis* from the collection of Rudolphi. It is very apparent that the term type specimens was here used in the older meaning of the term, indicating a type-lot of material upon which a specific description was based, not referring to a single individual. In spite of the fact that these specimens had been preserved in alcohol for almost a century they were in good condition for examination. Because of the difficulties involved in the technic of dehydrating and clearing Acanthocephala, and because of the uncertainty of the success accompanying this procedure with such a limited number of unreplaceable specimens, the writer confined his examination to those observations which could be made upon the specimens while in alcohol.

Unfortunately, the individuals were both males, and consequently no facts regarding the embryos were available. The proboscis, fortunately, was extended fully in both specimens. The body of only one of the worms was perfect, the other lacking the posterior region of the body. In Table III the perfect individual is referred to as 1179A; the mutilated one, as 1179B. Careful observations were made upon the proboscis hooks of these specimens, but since the specimens were not cleared, measurements of hooks could be obtained for only those portions protruding beyond the proboscis-wall. As shown in the table, the two individuals differed considerably in the length of the exposed portions of the hooks (see also Pl. XXVIII, Fig. 42, 43). It is interesting to note that this type material furnishes the key to an understanding of the variability in hook-length found for different individuals of this species as brought out in a later part of this paper.

TABLE III

DATA FROM STUDY OF "TYPE" MATERIAL OF *N. agilis* (Rud.)

	Body-length	Proboscis		Length, exposed portion of hooks		
		Length	Width	Terminal	Middle	Basal
1179 A	3.3 mm.	160 μ	148 μ	49 μ	16 μ	11 μ
1179 B	Incomplete	148 μ	153 μ	54 μ	21–27 μ	20 μ

COMPARISON OF *N. agilis* DATA FROM VARIOUS SOURCES

Through the generous response of Professor Corrado Parona, of Genoa, and of Professor Fr. Sav. Monticelli, of Naples, the writer was supplied with collections for comparison with the "type" specimens 1179A and 1179B. The close resemblance between alcoholic specimens received

from these two investigators and the two "types" in question left no room for doubt of their specific identity. The writer has since made careful study of stained whole-mounts and of serial sections with a view towards a more exact determination of the characters of the species as defined by Rudolphi.

Specimens received from Professor Monticelli collected at Trieste by Stossich from Mugil sp?, possess hooks of uniformly smaller average size (Pl. XXVIII, Fig. 38, 39) than those collected by Professor Parona from *Mugil auratus* and *M. cephalus* at Genoa. The differences are not, however, great; nor are they discontinuous (Fig. 36, 37). In all instances the ranges in size of the various hooks for the two collections overlap. This may indicate a slight tendency within this species toward the differentiation of geographical varieties. Varieties have not, however, become definitely enough fixed to warrant an attempt to separate them. In the light of this evidence of divergence it seemed worth while to investigate typical instances of measurements ascribed to members of this species by various writers. Table IV presents data for this comparison.

TABLE IV

DATA FROM DESCRIPTIONS OF *N. agilis*

(Measurements are in μ)

Observers	Date	Locality	Number of circles of hooks	Number of hooks in each circle	Length of terminal hooks	Length of middle hooks	Length of basal hooks	Proboscis length	Proboscis diameter	Length of embryos	Diameter of embryos	Number of testes
Dujardin	1845	Toulouse and Rennes	3	6	110	74	65	140	.....	43	14	3
Stossich	1885	Trieste ?	3-4	6?	.....	.....	.....	.....	.....	.....	.....	3
Hamann	1895	?	3	6	150	70	[70?]	.....	.....	26	.....	2
Condorelli	1898	Rome	3	6	131	85	65	334	250	36	15	
Porta	1905	?	3-4	6?	70	50	20	200-300	100-200	26		
Van Cleave (Monticelli Coll.)	1919	Trieste	3	6	94-106	41-82	30-65	150-250	185-230	30-41	12-15	2
Van Cleave (Parona Coll.)	1919	Genoa	3	6	94-120	65-83	41-71	180-270	150-200	30-41	12-15	2

The cement gland in this species has been very generally misinterpreted. Dujardin, in describing three testes, obviously mistook the cement gland for a testis. Stossich made the same error. Hamann reported six cement glands, though in fact only a single large syncytial

mass is present. Bieler has called attention to the fact that this peculiar type of cement gland is distinctive for the family Neoechinorhynchidae and has discovered that eight giant nuclei are always present in the cement gland of *N. agilis.* The last statement has been corroborated by the observations of the present writer.

Stossich was in error in regard to the number of circles of hooks upon the proboscis. It seems probable that this error resulted from his basing his description upon the study of a poorly executed drawing (see Fig. 41, Pl. XXVIII) in which the hooks of the terminal circle were so grossly distorted that they have the appearance of belonging to two entirely distinct circles. Notwithstanding the fact that Porta (1905 : 213) in the explanation of his plate indicates that Figure 12 of *N. agilis* is original, it bears a striking likeness (see Fig. 40, Pl. XXVIII) to the figure given by Stossich (1885). The peculiar misrepresentation of the hooks and of their arrangement is identically the same in the two figures. The two hooks of the terminal circles seen in profile appear to be of an entirely different order from the remaining hooks of that circle, which are much distorted through foreshortening. As a consequence of this error in observation Porta (1905 : 166) was induced to consider *Echinorhynchus hexacanthus* Dujardin as a synonym of *N. agilis,* believing the species to be greatly variable not only in regard to the dimensions of the hooks, but with reference to the number of hooks as well. In spite of this belief, his own description of *N. agilis* ignores the extent of this variability and includes but a single measurement for each type of hooks.

The present writer, after examining hundreds of specimens belonging to four different species of Neoechinorhynchus, has failed to find a single individual deviating from the typical arrangement of three circles bearing six hooks each. In Porta's description his "armata di 15–18 uncini disposti in 3–4 serie.", implies a variation which would necessitate a revision of the original description of the species, since even as early a worker as Rudolphi included in his description of the species a statement of the constant relations of these hooks. Porta's statement, involving a radical departure from the observations of other workers in the field, must inevitably be regarded as problematical in the highest degree.

Variability in *N. agilis*

As shown in Table IV, Hamann has given a measurement for the terminal hooks of *N. agilis* more than twice that given by Porta, yet neither writer has given any attention to the range of variability in the size of the hooks. It is not impossible that Porta considered only the protruding portions rather than the entire hooks, but even on this assumption his descriptions and his drawings can not be made to agree. According to his text, hooks of the basal circle are less than half the length of those in the middle circle; yet his figure shows practically no difference in the lengths of these two types of hooks.

In considering the range of variability of the proboscis hooks for any species of Acanthocephala the mechanical difficulties involved in obtain-

ing exact measurements of these structures must be duly regarded. Exact measurements are possible only in cases where the hooks are viewed in full profile; accordingly, in a permanent mount usually not more than one or two hooks of any given circle will afford conditions for obtaining an accurate determination of the maximum length of the hooks. For all other hooks there is usually a foreshortening produced by the angle at which the hooks protrude toward the observer from the proboscis-wall. In order to determine the extent to which variability in hook-length may go in *N. agilis*, the writer has taken numerous measurements in which especial care was exercised to eliminate inexact and incorrect observations. In Table V are brought together a few typical examples of measurements which were obtained from a study of individuals from the collections of Parona and of Monticelli.

TABLE V

VARIABILITY OF HOOK-LENGTH IN *N. agilis*

(Measurements are in μ)

Slide No.	Sex	Terminal hooks, length	Middle hooks, length	Basal hooks, length
Parona Coll.				
618	♀	94	— *	41–47
619	♂	120	71	59
620	♀	120	71	59–65
622	♂	120	77	71
623	♂	120	65	65
624	♂	120	83	59–71
Monticelli Coll.				
714	♂	94–100	53	35
715	♂	100	53	30
716	♂	94–100	41–47	30–35
717	♀	tips broken	47	35
718	♀	tips broken	47–53	35
719	♂	106	71–82	53–65
720	♂	106	65–71	47

* No hook in a position for an accurate measurement.

Because of the differences in data concerning *N. agilis* presented by various workers, only a part of which seem explicable on the ground of individual variability within the species, it seems desirable that a full statement be given covering the diagnostic characteristics of this species. The following description is based upon the comparison of recent European collections with Rudolphi's types of the species. In the case of varying structures an attempt has been made to indicate the usual range of such variability.

NEOECHINORHYNCHUS AGILIS (Rudolphi, 1819)

(Pl. XXVIII, Fig. 36–44)

Specific Diagnosis.—Maximum diameter in anterior third or fourth of body. From this region body tapers gradually toward each extremity.

Proboscis usually slightly longer than wide, provided with three circles of six hooks each. Hooks of terminal circle provided with a conspicuous reflexed root-process approximately one-half the length of the hook proper. Terminal hooks 94 to 120 μ long. Middle circle composed of hooks 41 to 83 μ long, with one short basal process extending anteriorly and another posteriorly from the point of origin of the hook proper. Basal hooks 30 to 71 μ long with no conspicuous root, frequently with a small process similar to the one described for the hooks of the middle circle. Embryos within the body of gravid female approximately elliptical, 26 to 41 μ long by 12 to 15 μ in diameter. Testes two, approximately elliptical, in broad contact with each other; followed posteriorly by a syncytial cement-gland containing eight giant nuclei.

Type host, *Mugil cephalus;* intestine infested.

Type locality, Spezia, Italy.

Distribution.—The writer has already (1913 : 188) called attention to the fact that records by Linton of the occurrence of this species in North American fish are based upon misidentifications. It is interesting to note that while *Mugil cephalus* and other species of the same genus occur along the Atlantic coast of North America, no Acanthocephala have been reported from any of them in Linton's extensive records of the examinations of marine fish for parasites.

The reports of *N. agilis* from Scotland by Thomas Scott and from France by Dujardin are the only other reports known to the writer of the supposed occurrence of this parasite outside the Mediterranean region. Of these, Scott's identification is not at all certain. General appearance of the parasite and the species of the host were the only two points which caused him to place his specimens under this name. His figures are clearly enough of a species of Neoechinorhynchus, although they are not distinctive or definite enough to justify the assumption that they represent *N. agilis.*

It seems probable that *N. agilis* is restricted in its distribution to the fishes of the genus Mugil in the Mediterranean region.

Neoechinorhynchus rutili (Müller, 1780)

Of the fresh-water representative of this genus in Europe, the writer has not been able to secure specimens for study. European investigators seem inclined to agree with Lühe in regarding *Echinorhynchus clavaeceps* as a synonym of *N. rutili.* This last species thereby becomes the only valid species of the genus reported from fresh-water fishes of central Europe. This claim of synonymity is obviously based upon a literature study rather than upon examination of type specimens of the species concerned. Much of the work of European investigators has unfortunately been of this character. It is certain that none of the early descriptions, dating back more than a century, include data which, alone, would suffice to differentiate species of the family Neoechinorhynchidae. The following table indicates typical discrepancies in the data recorded for *N. rutili (= E. clavaeceps).*

TABLE VI

DATA FROM DESCRIPTIONS OF *N. rutili* AND *E. clavaceps*

(Measurements are in μ)

Author	Date	Species	Length of hooks			Embryos
			Terminal	Middle	Basal	
Lühe.....	1911	*rutili*	170	100	[100?]	38 by 19–21
Hamann.....	1891	*clavaeceps*	70	30	[30?]	41
Porta.....	1905	*clavaeceps*	70	30	[30?]	35 by 17
Dujardin.....	1845	*clavaeceps*	67	44	41	41

The fresh-water representatives of this genus in Europe truly need the attention of some careful worker to ascertain if all belong to the same species. If Lühe's synonymy is correct some one should study the interesting case of variability in *N. rutili* since he reports specimens having terminal hooks 170 μ long, while Hamann found that typical individuals had hooks but 70 μ long. If one could have implicit faith in the data presented by these authors there would be ample ground for the recognition of two distinct species; but their descriptions are too inconsistent and contradictory to justify such a course. Hamann (1891, Pl. IX, Fig. 3) figures the terminal hooks of *E. clavaeceps* as less than 50 per cent. longer than the hooks of the middle circle, while in the same article he *describes* them as more than twice as long. Similarly, in Figure 17 of the same plate he shows the terminal hooks as only 25 per cent. longer than those of the middle circle. Lühe (1911, Fig. 2) obviously made an error in the calculation of the magnification of his drawing of the proboscis of *N. rutili*. On the basis of the stated magnification the terminal hooks are only 64 μ long, instead of 170 μ as stated in the text.

Since *N. rutili* is regarded as the type of the genus, it is an unfortunate circumstance that there is so great lack of agreement in the available descriptions. If Porta, Dujardin, and Hamann are correct, the chief means of distinguishing this species from *N. agilis* lies in the smaller size of the terminal proboscis-hooks of the former, though Lühe would have us believe that the chief distinction lies in the larger terminal-hooks of *rutili*. Bieler has offered one means of separating *N. agilis* and *N. rutili* based upon the number of giant nuclei in the cement gland of the male, but he simply states that the former has eight giant nuclei while the latter has twelve. He has given no statement of other diagnostic features available for the separation or characterization of the species.

THE IDENTIFICATION OF SPECIES

The Acanthocephala present few characteristics available for ready identification of species. Through adaptation to the parasitic habit the body proper has become reduced to little more than an elongated sac

containing the reproductive organs. With few exceptions this sac presents the same external appearance in different species, though members of some genera are readily distinguishable by the presence of spines upon the body-covering. General body-shape and size differ with the age of the individuals, but certain features of body-form are of value in the recognition of species if used in connection with other characters of a more stable nature. In view of this fact, outline drawings of entire individuals of many of the species are presented, for the first time, in this paper.

Unfortunately, the proboscis, upon which much importance is placed in classification, is frequently completely invaginated within the body. Living specimens may be induced to protrude the proboscis if left for a few minutes in a dish of plain water, though they are best studied in normal salt-solution.

Stained whole-mounts and sections are needed for the study of internal organs and for an accurate study of the proboscis hooks. Preliminary to the preparation of these, the worms should be placed for about fifteen minutes in a saturated solution of corrosive sublimate to which enough acetic acid has been added to make a one per cent. mixture. After washing in water the specimens should be passed through 35 and 50, to 70 per cent. alcohol in which they may be kept indefinitely. In the preparation of whole mounts and of sections ordinary histological procedure is followed. Best results are obtained if the body wall is pierced in a number of places with a fine needle. This prevents shrinkage when specimens are changed from one liquid to another. A very dilute mixture of Ehrlich's acid hematoxylin in distilled water has been found to be one of the most valuable stains for whole mounts in damar and for sections.

In the following key an attempt has been made to utilize characters which are easily observable even in living or in alcoholic specimens. In most instances, however, the separation of species involves careful study of permanent mounts and of sections.

Key to Species from Fresh-water Vertebrates Exclusive of Birds

1(24) Body proper devoid of spines—an elongated sac, approximately circular in cross-section; surface smooth or slightly folded to produce slight wrinkling.....2

2 (3) Anteriorly the body proper passes over into a long cylindrical neck of considerably smaller diameter than the body. In freed specimens the anterior extremity of neck shows a spherical enlargement. Proboscis and this enlargement both usually embedded in the tissue of host intestine. Host a fish.....*Pomphorhynchus bulbocolli* Linkins, n. sp.

3 (2) Diameter of neck not conspicuously smaller than that of body proper. Neck never bearing a spherical enlargement.....4

4(15) Proboscis globular, bearing three circles of hooks. Body frequently showing slight protuberances along mid-dorsal line, indicating positions of giant nuclei. Cement gland of male a single syncytial mass..5

5 (6) Parasitic in intestine of turtles.....*Neoechinorhynchus emydis.*

6 (5) Parasitic in intestine of fish.....7

7 (8) Proboscis bearing three circles of twelve hooks each..... .....*Gracilisentis gracilisentis.*

8 (7) Proboscis bearing three circles of less than twelve hooks each.....9

9(10) Eight hooks in each circle.....*Octospinifer macilentus*, n. sp.

10 (9) Six hooks in each circle.....11

11(12) Hooks of basal circle over 40 μ long. Body wall about 80 μ thick..... .....*Neoechinorhynchus crassus*, n. sp.

12(11) Hooks of basal circle less than 40 μ long.....13

13(14) Body very long, approximately cylindrical. Embryos within body of gravid female usually over 48 μ long..*Neoechinorhynchus cylindratus.*

14(13) Body tapering conspicuously from anterior region toward the posterior extremity. Embryos within body of gravid female less than 45 μ long.....*Neoechinorhynchus tenellus.*

15 (4) Proboscis variable in shape but never globular; always bearing more than three circles of hooks.....16

16(17) Proboscis long, approximately cylindrical. Body of almost same diameter throughout. Cement gland a single syncytial mass. Proboscis receptacle a single walled sac. Giant nuclei of subcuticula plainly observable in stained specimens.....*Tanaorhamphus longirostris.*

17(16) Proboscis long or approximately ovoid. Male bearing several separate and distinct cement-glands, variously grouped. Proboscis receptacle a double-walled sac. Nuclei of subcuticula small and numerous or finely dendritic.....18

18(19) Brain located at base of proboscis-receptacle. Retinacula coming off from posterior end of receptacle. In intestine of amphibian..... .....*Acanthocephalus ranae.*

19(18) Brain located some distance anterior to the posterior end of proboscis-receptacle. Retinacula given off from sides of receptacle.....20

20(23) Anterior region of body slightly inflated and larger than posterior portion, which tapers gradually toward posterior extremity.....21

21(22) Proboscis bearing sixteen longitudinal rows of hooks. Embryos within body of gravid female 115 to 165 μ long, the middle membrane drawn out into polar prolongations more than twice as long as wide..... .....*Echinorhynchus salvelini.*

22(21) Proboscis bearing twelve longitudinal rows of hooks. Embryos within body of gravid female 51 to 91 μ long, the polar prolongations of middle membrane usually not much longer than wide..... .....*Echinorhynchus coregoni* Linkins, n. sp.

23(20) Body tapering gradually from anterior region posteriorly. Lemnisci long. Embryos 80 to 110 μ long.....*Echinorhynchus thecatus.*

24 (1) Body proper provided with cuticular spines in anterior region. Proboscis long, cylindrical. Parasitic in intestine of fish.....25

25(26) Proboscis armed with twenty-two to twenty-four longitudinal rows of hooks.....*Rhadinorhynchus ornatus.*

26(25) Proboscis armed with ten to fourteen longitudinal rows of hooks..... .....*Rhadinorhynchus tenuicornis.*

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Explanation of Plates

All figures unless otherwise indicated are original and were drawn with a camera lucida. In closely related species all drawings of the same structures are drawn to the same scale, thus permitting direct comparison of figures.

SYMBOLS USED

c, cuticular sheath surrounding proboscis hooks
cg, cement gland
g, ganglion of central nervous-system
gn, giant nucleus
l, lemniscus
n, neck
p, polar prolongation of middle membrane of embryo
r, receptacle of the proboscis
t, testis

July, 1919.

Plate XXII*

Echinorhynchus thecatus

Fig. 1. Optical section of immature male showing general form and arrangement of organs. Sexual organs in this individual not mature. From intestine of *Micropterus salmoides*. Stained with hematoxylin and mounted in damar.

Fig. 2. Profile of dorsal surface of proboscis, showing a single longitudinal row of hooks. Same individual as shown in Fig. 1.

Fig. 3. Embryo from body-cavity of mature female.

Fig. 4. Profile of proboscis, ventral surface, showing a single longitudinal row of hooks.

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*The scale indicating magnification of Fig. 1 has a value of 1 mm.; that of Fig. 2 and 4, 0.1 mm.; that of Fig. 3, 0.05 mm.

PLATE XXII

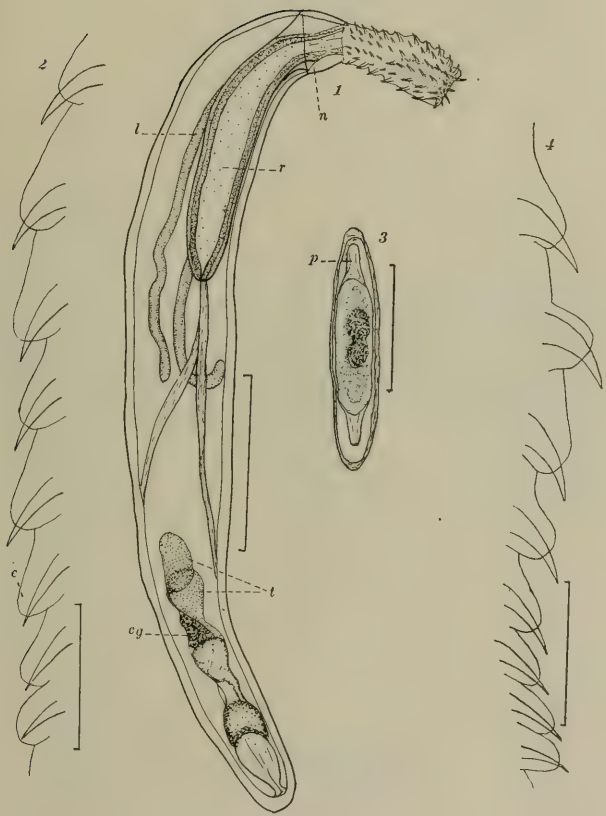

PLATE XXIII *

Fig. 5. *Echinorhynchus salvelini.* Embryo from body-cavity of gravid female, showing very long polar prolongations of middle membrane.

Fig. 6. *Echinorhynchus coregoni.* Embryo from body-cavity of gravid female, showing short polar prolongations of middle membrane.

Fig. 7. *Pomphorhynchus bulbocolli.* Optical vertical section of immature male taken from intestine of *Ameiurus nebulosus.* Whole mount, stained with hematoxylin and mounted in damar.

Fig. 8. *P. bulbocolli.* Embryo from body-cavity of gravid female taken from intestine of *Ictiobus urus.*

Fig. 9. *Rhadinorhynchus tenuicornis.* (Van Cleave, 1918a.)

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* Scales indicating magnification have a value of 0.05 mm. in all figures except Fig. 7, in which the scale-value is 1 mm.

PLATE XXIII

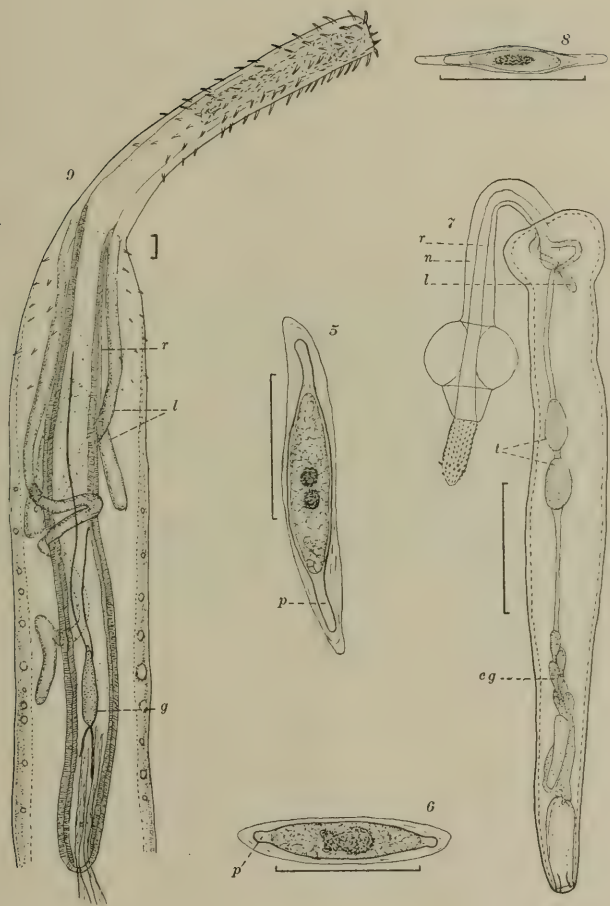

Plate XXIV *

Fig. 10. *Echinorhynchus salvelini.* Profile of ventral margin of proboscis of fully mature female. Stained in hematoxylin and mounted in damar.

Fig. 11. *Echinorhynchus coregoni.* Profile of ventral margin of proboscis of fully mature female. Stained in hematoxylin and mounted in damar.

Fig. 12. *E. salvelini.* Outline showing general body-form of fully mature female. Body cavity is so packed with embryos that internal structures are completely obscured. Whole mount in damar.

Fig. 13. *E. coregoni.* Outline of fully mature female. Note contrast in body-form and size of this species and of *E. salvelini.*

Fig. 14. *Neoechinorhynchus emydis.* Surface view of proboscis of fully mature female from intestine of *Graptemys pseudogeographica.* Hematoxylin-stained specimens in damar.

Fig. 15. *N. cylindratus.* Surface view of proboscis of fully mature female from *Micropterus salmoides.* Whole mount in damar.

Fig. 16. *N. tenellus.* Surface view of proboscis of fully mature female from *Stizostedion vitreum.* Stained in hematoxylin and mounted in damar. The hook shown in broken outline lies behind the median plane. Terminal hooks in this species point more directly backward than in other members of the genus.

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* Scales indicating magnification of Fig. 12 and 13 have a value of 1 mm.; all others in the plate have a value of 0.05 mm.

PLATE XXIV

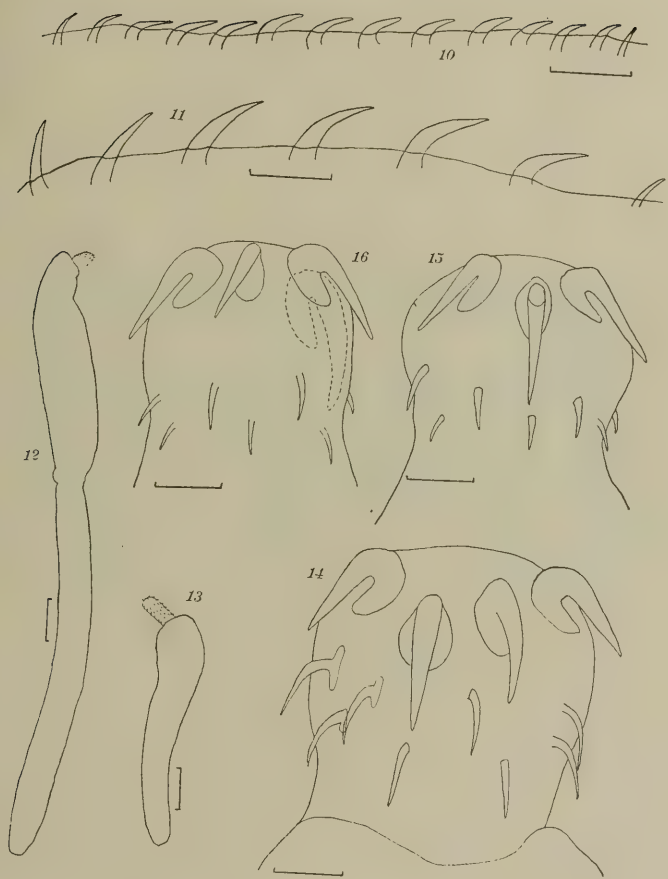

Plate XXV *

Fig. 17. *Neoechinorhynchus cylindratus.* Outline showing general body-form and size of fully mature female from intestine of *Micropterus salmoides.* Positions of giant nuclei of subcuticula are indicated. Body completely filled with developing embryos, which obscure all internal structure. Hematoxylin-stained mount in damar.

Fig. 18. Embryo from body-cavity of female shown in Fig. 17.

Fig. 19. *N. tenellus* from intestine of *Stizostedion vitreum.* Outline of gravid female, showing general body-form. Hematoxylin-stained whole-mount in damar.

Fig. 20. Embryo from body-cavity of specimen shown in Fig. 19.

Fig. 21. *Neoechinorhynchus emydis* from intestine of *Graptemys pseudogeographica.* Outline showing general body-form of gravid female with body-cavity completely packed with embryos.

Fig. 22. Optical section of immature male of same species. A comparison of this figure with the preceding one shows how slightly the increase in body size due to growth modifies the general body-form.

Fig. 23. Embryo from body-cavity of gravid female of same species.

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* Scales indicating magnification of Fig. 17, 19, and 21 have a value of 1 mm.; all others in the plate have a value of 0.05 mm.

PLATE XXV

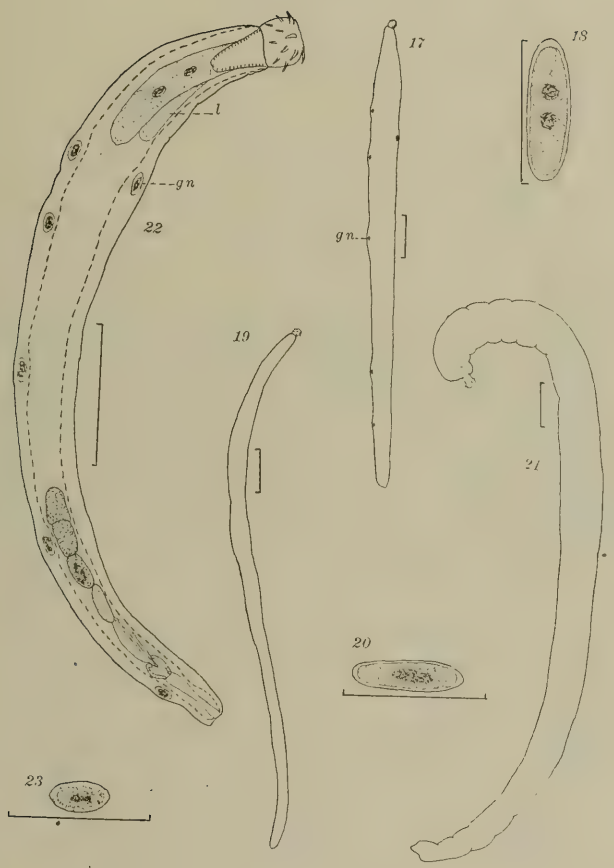

PLATE XXVI *

Fig. 24. *Neoechinorhynchus crassus*, n. sp., from intestine of *Catostomus commersonii*. Optical section of mature male, showing arrangement of internal organs and relative thickness of body-wall. Hematoxylin-stained whole-mount in damar.

Fig. 25. Surface view of proboscis of same individual.

Fig. 26. *Octospinifer macilentus*, n. sp., from intestine of *Catostomus commersonii*. Optical section of mature male. From hematoxylin-stained whole-mount in damar.

Fig. 27. Surface view of proboscis of same individual.

Fig. 28. *Neoechinorhynchus crassus*. Embryo from body-cavity of gravid female.

Fig. 29. *Octospinifer macilentus*. Embryo from body-cavity of gravid female.

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* Scales indicating magnification of Fig. 24–26 have a value of 1 mm.; all others in the plate have a value of 0.05 mm.

PLATE XXVI

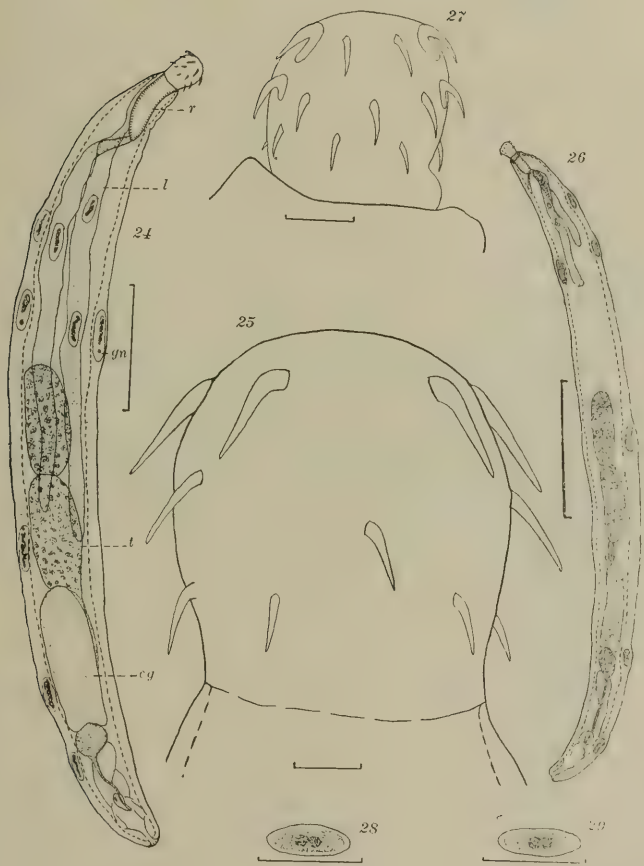

Plate XXVII *

Fig. 30. *Gracilisentis gracilisentis* from intestine of *Dorosoma cepedianum*. Optical section of fully mature male. Whole mount in balsam, stained in hematoxylin.

Fig. 31. Surface view of proboscis of gravid female of same species, showing types of hooks and their arrangement. Paracarmine-stained whole-mount in balsam.

Fig. 32. Embryo from body cavity of gravid female of same species.

Fig. 33. *Tanaorhamphus longirostris* from intestine of *Dorosoma cepedianum*. Optical view of fully matured male. Hematoxylin-stained specimen in balsam.

Fig. 34. Embryo from body-cavity of gravid female of same species.

Fig. 35. Hooks from surface of proboscis of gravid female of same species, showing difference in size and form characteristic of different regions: *(a)* profile of eighth hook from base of proboscis in one of the longitudinal rows upon the ventral surface; *(b)* fifth hook from the base in a row upon the lateral surface of proboscis; *(c)* fourth hook from base of proboscis in a longitudinal row upon the ventral surface.

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* Scales indicating magnification of Fig. 30 and 33 have a value of 1 mm.; all others in the plate have a value of 0.05 mm.

PLATE XXVII

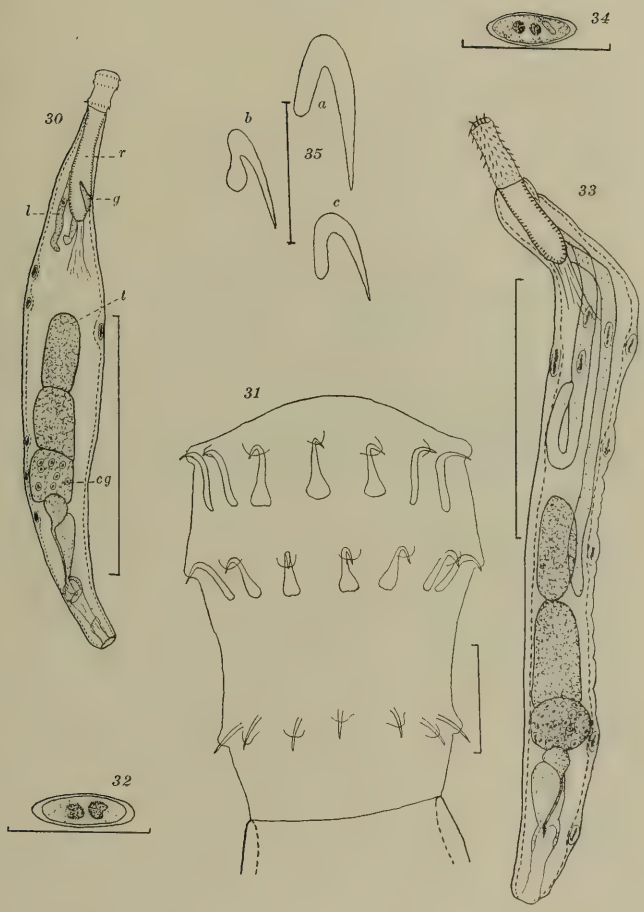

Plate XXVIII *

Neoechinorhynchus agilis

(Fig. 36–39 illustrating variability in proboscis and in hook-length)

Fig. 36. Hooks from a long-hooked individual (male) from the collection of Parona: *(a)* hook from terminal circle; *(b)* hook from middle circle; *(c)* hook from basal circle,—all in full profile.

Fig. 37. Surface view of proboscis of a typical long-hooked individual from collection of Parona. In this figure and in Fig. 39 the hooks on the extreme back of the proboscis are omitted. Roots of hooks, shown in broken outline, lie behind the median vertical plane.

Fig. 38. Hooks from short-hooked individual (male) from the collection of Monticelli. Letters have same significance as in Fig 36.

Fig. 39. Proboscis of a typical short-hooked individual from above collection.

Fig. 40. Proboscis. (Copied from Porta—1905, Pl. I, Fig 12. Surface-shading omitted.)

Fig. 41. Proboscis. (Copied from Stossich—1885, Fig. 19.)

Fig. 42. Proboscis of 1179B—an alcoholic specimen from "type" material of Rudolphi.

Fig. 43. Proboscis of 1179A—alcoholic specimen from same material.

Fig. 44. Embryo from body-cavity of gravid female from collection of Monticelli.

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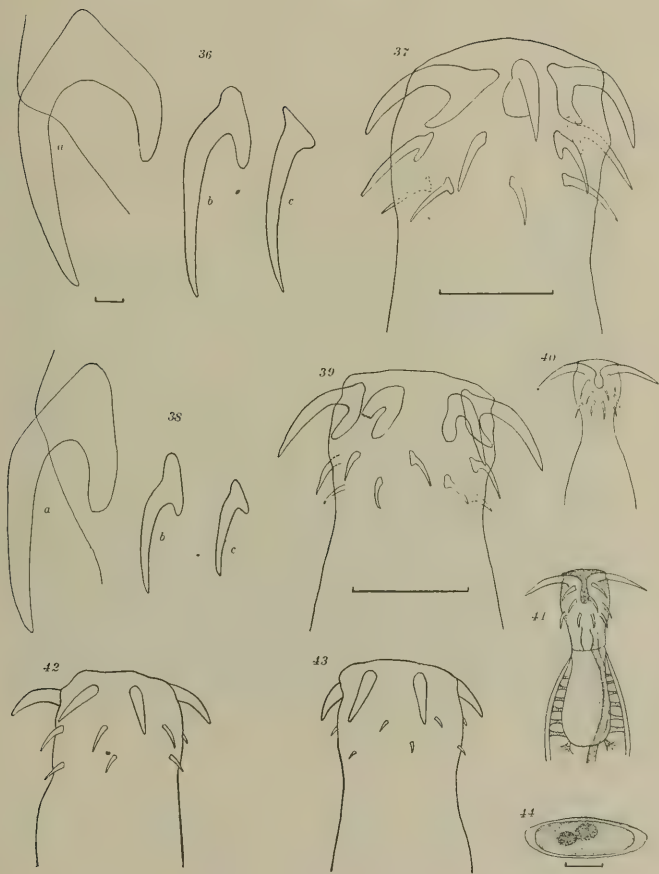
* Scale indicating magnification of Fig. 44 has a value of 0.01 mm.; all other scales in the plate have a value of 0.1 mm.

PLATE XXVIII



ARTICLE IX.—*Foot-rot Disease of Wheat—Historical and Bibliographic.* BY F. L. STEVENS.

In April, 1919, a serious wheat disease was noted in Madison and other counties in Illinois; also in several counties in Indiana. Its most constant character is a darkening, and in severe cases a rotting,

FIG. 1. Wheat plants from Madison County, Illinois, showing typical foot-rot. Three of the plants show the characteristic development of extra shoots.

of the basal portion of the stem.* By various means—telegram, mimeographed letters and circulars, and public notice— the U. S. Department of Agriculture, and its agents, have announced the disease as almost certainly "take-all" (180) (181) (182) (183) (184) (187). Take-all and diseases of similar character—known also as white heads,

* Other characters will be discussed in a later paper.

black-foot, black-stem, stalk disease, foot disease, root disease, foot-rot, wheat-stem killer, straw blight, piétin, pied noir des céréales, mal del piede, mal do pé do trigo, briseur de chaumes, brusone, fogheta, piétin du blé, maladie du pied, Fusskrankheit—occur in Italy, France, Germany, Belgium, Australia, Sweden, Finland, United States, Mexico, England, New South Wales, Holland, Russia, Brazil (?), and Japan, and have been attributed to several different fungi, but most prominently to Ophiobolus.

In connection with a study of the Illinois disease it was necessary to glean as many facts as possible from the literature concerning foot-rot, or take-all, and related diseases, and the large amount of material resulting suggested the utility of putting some of it into permanent form as a convenience to students of the subject. The following chronological account presents facts and opinions selected from important articles cited in the appended bibliography.

Disease of the nature of foot-rot is said by Mangin (158) to have been known in France as early as 1840. In 1823 (1), 1845 (2), 1856 (3), 1863 (4), 1875 (7), 1884 (11), 1887 (14), and 1897 (44) Ophiobolus was noted or collected on cereals, not, however, with reference to its pathogenic relation to the plant. The disease is said to have been noted in South Australia in 1852 (84). In 1864 Parliament appropriated £200 for the study of take-all and other cereal diseases (89), and in 1868 a report of a Commission on Diseases of Cereals was published in Australia (5). In this they say of take-all, "Its ravages are irrespective of climatic influence." In 1870 (6) a fungus was observed in the lesions.

In 1878 (8), in France, the first definite description of piétin was published, the disease being attributed to an excess of moisture and a mild winter. In 1880 (9) the disease was noted in Italy. In 1883 Saccardo (10) mentions Hendersonia as the conidial stage of Ophiobolus. In 1884 the first reference in England occurs under the name "straw blight" (12). Prillieux and Delacroix (16) in 1890 emphasize the importance of a brown mycelium and attribute the disease to *Ophiobolus graminis* Sacc. In 1892 Schribaux (19) noted that early varieties are most susceptible, and tried various control measures. Loverdo (20) reports the disease on Cynodon and Agrostis.

Cobb, in 1892 (22), in a rather extensive article, discusses the disease known as take-all as found in Australia and attributes it to *Cladosporium herbarum*. He advises rotation, drainage, good tillage, burning stubble, seed treatment, and resistant varieties. The disease was also noted as occurring in oats. Frank (23) (24) (25) (26) (27) in 1894 discusses foot-rot in Germany, as does also Hiltner (28) (29). In 1895 Saccardo and Berlese (34) note foot-rot in Italy and attribute it to *Sphaeroderma damnosum*. Frank in 1895 (30) notes *Leptosphaeria herpotrichoides* on rye and *Ophiobolus herpotrichus* on wheat. The mycelium grows into the roots, which become black and die. No conidial form was observed. In 1897 (43) the disease was noted on wheat, rye, and barley

in France. Prillieux (42) mentions the mycelium in the vessels, also in a brown surface development in flecks. McAlpine in 1898 (46) lists numerous fungi on diseased wheat, among them being *Cladosporium herbarum, Macrosporium graminum* and *M. cerealium,* and *Epicoccum neglectum.* He refers to Dr. Cobb's conclusion and says "It is premature to speak of it [*Cladosporium herbarum*] as the take-all fungus."

In 1898, 1899, and 1902 Mangin (47) (56) (70) contends that Leptosphaeria is the main cause of the disease and that Ophiobolus is secondary, as are also several other fungi which were present. Inoculations with spores in water suspension gave positive results. Frank in 1900 (64) describes *Ophiobolus herpotrichus* as the cause of the disease, while Delacroix (67) in 1901 asserts, on the basis of inoculation experiments, that both Leptosphaeria and Ophiobolus are parasitic, the disease appearing three or four months after inoculation. In 1901 Ophiobolus was first recorded in Australia (68). In 1902 Mangin (70) contends that Leptosphaeria is the primary cause and Ophiobolus of secondary importance.

In 1902 Cordley (75), in Oregon, notes a disease which from the description is indistinguishable from that now in Illinois. In 1904 McAlpine (84) claims to prove that Ophiobolus is the cause of take-all, since wheat planted in plots with diseased stubble became diseased and bore spores of Ophiobolus within fifty-two days. It is to be noted that McAlpine did not employ pure cultures, and it is not clear how he recognized with certainty "the young mycelium of Ophiobolus." In 1906 take-all was noted on barley and other grasses in Australia (89). Kirchner (90) holds that the disease follows weakening of the plant from other causes. Robinson, 1907 (93), notes perithecia in the sheaths, and says that wheat sown in diseased stubble soon becomes sick and in two months may all be dead and covered with perithecia. In 1908 Krüger (95) holds that fungi are not the immediate cause but that the disease is due to weakening of the plant. Richardson, in 1910 (111), in Australia, found upon close examination that the Ophiobolus vegetative mycelium was present in every case. "Swollen roots", he says, "were impregnated with a black sooty incrustation." He also notes the disease on Hordeum, and says that a good stubble-burn gives good crops following. Pridham, 1911 (112) describes the disease as negligible in favorable years, and adds that in all cases of disease there is a blackening of the stalk at the foot. Fron, in 1912 (120), notes the presence of felt-like brown masses and finds Leptosphaeria on all specimens; Ophiobolus, rarely. From infection experiments he concludes that Leptosphaeria is the cause. Eriksson, in 1912 (121), refers to Coniosporium as the conidial stage of the causal fungus. Averna-Sacca (124) writes in Brazil of the disease. Störmer and Kleine in 1912 (129) say the disease can also be caused by Typhula. Voges in 1912 (130) says that fungi are not the primary cause, but that the disease is due to lowering of the vitality of the wheat plant by environmental conditions. Schaffnit in 1912 (131) attributes a foot-rot of rye to *Fusarium nivale.*

Massee, 1912 (127), says that the mycelium forms a thin felt on the stem and sheaths and that a black superficial mycelium is also characteristic. Oats and wheat inoculated when about an inch high with *Ophiobolus graminis* were yellowed and drooping in six weeks, with characteristic mycelial infection. Bromus and Agropyron are also infected. Prunet, 1913 (138), concludes that either *Ophiobolus graminis, O. herpotrichus,* or *Leptosphaeria herpotrichoides* can cause the disease, and says that the name piétin is thus applied to three diseases with the common character of stem-blackening, and that each should be studied separately.

In 1913 Guerrapain and Demolon (139) (140) call particular attention to this disease following a mild winter. Voges, 1913 (143), in a very extensive article, concludes that the Ophiobolus ascospores can give rise to two kinds of mycelium, one of which is *Fusarium rubiginosum* A. & W.; that the Ophiobolus mycelium is not characteristic of foot disease and that the specific cause is not Ophiobolus; and that the disease has various causes, for example frost, the Ophiobolus appearing only after weakening due to other causes. Mangin, 1914 (158), says that both Leptosphaeria and Ophiobolus give a brown or black tint to the stem and roots. The presence of several Fusaria is also noted in connection with this disease. Berthault, 1914 (161), says that *Fusarium rubiginosum* is often present and perhaps causal. Voges, 1914 (162), says that the conidial form is not Fusarium but is Acremonium. Spafford, 1917 (175), suggests the name "wheat stem killer", and says that the disease may be recognized at the base of the stem, which is "covered with a brownish powder or stained brown." He regards this character as important in distinguishing this disease from the results of climatic action due to drying out, in which cases the plant is yellow throughout. He states that if wheat gets a good start, even in infected soil, but little injury follows. In 1917 (176) *Ophiobolus graminis* was reported on rice in Japan. In 1919 Brittlebank (179) lists as hosts, wheat, oats, barley, *Hordeum murinum, Bromus mollis, B. sterilis,* and *Agropyron scabrum.* In 1919 the latest paper available from Australia (178) is less definite as to etiology than are earlier Australian papers.

In the voluminous mass of evidence presented in these articles certain points stand out clear, others are far from clear.

Points of Agreement

1. A serious loss to the wheat crop in many countries arises from a diseased condition of the wheat plant which is aptly called foot-rot, black-foot, or black-stem, or, by the French, piétin, though known by many other names.

2. This disease is characterized by a darkening, blackening, or rotting of the lower stem, usually the first internode above the roots.

3. The disease always occurs in spots in the field.

Beyond these three facts there is practically little or nothing in which there is entire accord.

Points of Disagreement

These may be summarized as follows:

Symptoms.—Many observers describe as an essential symptom of foot-rot the presence of a *brown felt-like mycelial weft* on the diseased stem and adjacent sheath. Some describe it as a black crust. Others fail to find this, or at least do not mention it, while still others definitely assert that it is not an essential symptom.

Some describe the roots as swollen, blackened, or stunted, though most writers mention no root symptoms.

Most writers assert that if land on which the disease occurs is cropped with wheat the following year the disease will again appear, and often on a largely increased area. Some show by experiment that wheat planted in diseased stubble will become diseased; others say that succeeding crops may be healthy, and that the recurrence of the disease is dependent upon various factors, chief among which is the weather.

Etiology.—Most writers on foot-rot say that the causal fungus is *Ophiobolus graminis*; a smaller number that it is *O. herpotrichus.* Some merely report the presence of one or both of these fungi, while other investigators claim to have demonstrated their actual parasitism by inoculations with pure or nearly pure cultures of one or another of these fungi. Other writers claim that *Leptosphaeria herpotrichoides, Typhula graminis,* and *Cladosporium herbarum* are causal agents of foot-rot, while some assert that any one of several of the five fungi mentioned above may be the cause of the disease.

Some hold that these fungi are saprophytes or but weak parasites that can attack the wheat plant only when it is weakened by other causes, chiefly by cold.

Conidial stages of Ophiobolus.—Various claims have been made as to the conidial form of Ophiobolus. Some state that the fungus is usually sterile in its young stages. Some find as the conidial form a Coniosporium, an Acremonium, a Fusarium, or a Hendersonia.

Various prophylactic measures, as burning stubble, rotation, good culture, etc., have been suggested, but they are based on general grounds rather than specific knowledge of this disease, and will not be discussed.

In view of these conflicting observations and conclusions the most reasonable attitude is that of Prunet, Voges, and others, namely, that we have here several distinct diseases due to as many separate causes. Clearly science will be best served by such a conception.

So far as I can judge, the disease now present in Madison county, Illinois, is indistinguishable from that described by Cordley in Oregon, U. S. A., in 1902 (75), the cause of which he did not determine. I am not yet sure what the cause of the Madison county disease really is, but

as to the three points concerning which we have noted universal agreement it is no exception to the rule. I do not find in it the brown felt described by so many as characteristic of Ophiobolus, nor do I find constantly present any of the fungi mentioned above as the cause of foot-rot. Further long and patient investigation must determine which foot-rot, or which of its several types, is now interesting us in Illinois—if indeed it is any one of those yet studied.

The name take-all is linked in the literature with Ophiobolus, and if the disease in Illinois is caused by Ophiobolus this name may be used properly in connection with it, but unless this is the case I prefer to employ the more comprehensive general name, foot-rot.

Until definite knowledge is secured as to the cause of the disease it is impossible to predict its development, or to state whether it will recur in the same fields and spread to others. If it is identical with the Oregon disease which appeared in 1902 and apparently has attracted no attention since then (75), it may here lapse into a similar insignificant position. It should be borne in mind that the winter of 1918-19 was a very exceptional one and of the type that is most favorable to foot-rot in Europe, and that in the absence of such winters the foot-rot may do little harm.*

In our present state of ignorance as to the precise cause of this disease in Illinois it is impossible to give specific advice as to its prevention. A wise course, however, will be to avoid planting wheat for one year or, better, for two years, on lands where the disease occurred this year. Oats may probably be safely substituted. Burning over the stubble after harvest will also be a safe precaution.

Annotated Bibliography

EXPLANATORY

The asterisks used in connection with the entries indicate that the articles or books or pertinent passages cited have been carefully read in the original. My acquaintance with those not so marked has been gained through reviews or abstracts. The notes do not indicate the entire content of the articles, but call attention to points most important in connection with the Illinois disease or in the general history of foot-rot. Information given in the preceding pages is not, as a rule, repeated in the notes.

Quite a number of the entries lack the author's name, since they either appeared anonymously or in secretarial or journal reports. Other entries are without title because they so appeared in foot-notes of articles read. It seemed ill-advised to omit them, though I was unable to verify the citations. For the sake of brevity the abbreviation E. S. R. is used to indicate the "Experiment Station Record" published by the U. S.

* Since the above was written, Dr. A. D. Cotton, of the Pathological Laboratory of the Kew Botanic Gardens, has examined the foot-rot in Illinois, and he tells me that the specimens he examined lacked the distinctive characters of take-all as that disease is understood in England.

Department of Agriculture; and Zeit. f. Pfk., for Sorauer's "Zeitschrift für Pflanzenkrankheiten."

ACKNOWLEDGMENTS

I am indebted to Miss C. R. Bennett, of the Library of the U. S. Department of Agriculture, for four titles which I should not have had but for her courtesy; to Mr. P. L. Windsor, Librarian of the University of Illinois, who secured for me very many original articles; and to Mrs. E. Young True for assistance in the preparation of the manuscript.

Fries, E.

*(1) 1823. Systema mycologicum, 2: 504.
Sphaeria herpotricha listed.

Mougeot, A.

(2) 1845. Champignons des Vosges, Épinal, p. 102.

Marchand.

(3) 1856. Sylloge—p. 251.

Tulasne, L. and C.

*(4) 1863. Selecta fungorum carpologia, 2: 255. Paris.
Mentions Ophiobolus under name *Rhaphidophora herpotricha.*

Commission on Diseases of Cereals

(5) 1868. Report on diseases of cereals. Adelaide, S. Austral.

Muecke, Carl

(6) 1870. The take-all (*Xenodochus cercalium*). Prize essay, published under the authority of the Board of Agriculture of Victoria.
Observed a fungus in the disease lesions. Estimated loss in South Australia at £6,000,000.

Saccardo, P. A.

(7) 1875. Fungi Veniti novi vel critici. Nuovo Giorn. Bot. Ital. Vol. 7.

(8) 1878. Sur l'état de la récolte du blé et sur la maladie du piétin. Bul. des séances de la Soc. Centrale d'Agr. de France, 38: 368.
First adequate description of the disease; "la cause du mal soit généralement attribuée à l'humidité."

Cugini

(9) 1880. Supra una malattía del frumento recentmente composa nella Provincia di Bologna. Giorn. Agr. Ital. 14: No. 13.
Noted the disease as serious near Bologna.

Saccardo, P. A.
*(10) 1883. Sylloge fungorum omnium hucusque cognitorum, 2:352.
Says conidial form of *Ophiobolus herpotrichus* is a Hendersonia.

Brunaud
(11) 1884. Description des Sphaeriacées des environs de Saintes, La Rochelle, p. 213.

Smith, W. G.
*(12) 1884. Diseases of field and garden crops, p. 69.
Describes lesion at base of the stem and fungus present there. No spores known.

Morini
(13) 1886. ———. Nuova Giorn. Bot. Ital. 18:32.
Noted *Ophiobolus herpotrichus*, but regards it as a saprophyte.

Winter, G.
*(14) 1887. Die Pilze Deutschlands, Oesterreichs und der Schweiz. Rabenhorst's Kryptogamen-Flora von Deutschland, Oesterreich und der Schweiz, 1 (Abth. 2): 523, 524.

Pearson, A. N.
*(15) 1888. Blight in wheat. Dept. Agr. Victoria, Bul. 1:38.
Says there is a general consensus of opinion that this is a poverty disease, and that the fungus which causes take-all attacks mainly such crops as are insufficiently nourished.

Prillieux and Delacroix
*(16) 1890. La maladie du pied du blé causée par l'*Ophiobolus graminis* Sacc. Bul. Soc. Myc. de France, 6:110.
Authors note brown mycelium in flecks; perithecia in winter; and mycelium in all browned tissues.

Cugini
(17) 1890. ———. Bol. Staz. Agr. Modena, 9:46.

McAlpine, D.
(18) 1891. ———. Dept. Agr. Victoria, Bul. 14. Cited by McAlpine in (46).

Schribaux, E.
*(19) 1892. Le piétin ou maladie du pied des céréales. Jour. d'Agr. Prat. 2:317–320.
Accepts Ophiobolus as the cause of the disease.

Loverdo, J.
*(20) 1892. Les maladies cryptogamiques des céréales, p. 231, 236.
Reports *Ophiobolus herpotrichus* on Cynodon and Agrostis.

Tepper, J. G. O.
*(21) 1892. "Take-all" and its remedies. Agr. Gaz. N. S. Wales, 3:69–72.
Says that "Take-all is nothing else than starvation of the crop."

Cobb, N. A.
*(22) 1892. Plant diseases and how to prevent them. Agr. Gaz. N. S. Wales, 3: 991–1001.

Notes false theories as to take-all: due to insects, weeds, nematodes, soil deficiency, poor drainage, poor tillage. Characters: occurs in patches; plants in a majority of cases dry up when young; much *Cladosporium herbarum* and *Septoria graminum* present, the latter yellowing the leaf (which later dies) and being fatal when on the sheath of young plants, the former fungus found in nearly all cases of take-all; internal mycelium colorless, conidiophores tufted, usually emerging through stomata; typical spore two-celled and rough.

"I will * * * assign to the *Cladosporium herbarum* the name of take-all, to *Septoria graminum* the appropriate name of dry blight, to the Macrosporium the name of brown blight."

Frank, A. B.
*(23) 1894. Das Umfallen des Roggens. Deut. Landw. Presse, 21 (No. 51): 509.
*(24) 1894. Die diesjährigen neue Getreidepilze. Deut. Landw. Presse, 21 (No. 67): 644–645.

Notes *Leptosphaeria herpotrichoides* on rye as a parasite. It has long been known on stubble as a saprophyte. The base of the stem is browned and weakened. Notes also *Leptosphaeria tritici* and *Ophiobolus herpotrichus* causing a foot-rot, and the latter fungus also killing the roots of winter wheat.

(25) 1894. [A stem disease of wheat.] Deut. Landw. Presse, p. 675.
*(26) 1894. Mitteilungen des Sonderschusses für Pflanzenschutz. Mitt. deut. landw. Ges. 1894 (No. 6): 90, 91; and No. 8: 17. Abs. in E. S. R. 6: 312.

Describes Leptosphaeria on rye and wheat, and Ophiobolus on wheat.

(27) 1894. ———. Deut. Landw. Ztg. 37 (No. 124): 740. Cited by Krüger in (95).

Hiltner, L.
*(28) 1894. Die Fusskrankheit des Getreides. Sächs. Landw. Ztg. No. 33: 397–401.

A hyaline mycelium was present in the roots and in the lower stem, and a dark mycelium on the surface. Hendersonia and Ophiobolus were found.

(29) 1894. ———. Mitt. Pfk. Vers. Stat. Tharand.

Frank, A. B.
*(30) 1895. Über die in Deutschland neu aufgetretenen Getreidepilze. Zeit. f. Pfk. 5: 11, 12.

Mentions *Leptosphaeria herpotrichoides* on rye, *L. tritici* on wheat leaves. *Ophiobolus* (*Raphidospora* [*Raphidophora*]) *herpotrichus* is reported as "now" found in Germany. The mycelium often goes to the roots, which turn black and die.

*(31) 1895. Die neuen deutschen Getreidepilze. Ber. deut. bot. Ges. 13 (No. 2): 61–65. Abs. in E. S. R. 6: 909.
(32) 1895. ———. Jahrb. d. Sondera. f. Pfl. Heft 19: 11, 12,
(33) 1895. ———. Deut. Landw. Ztg. 38 (No. 40): 325. Cited by Krűger in (95).

Saccardo, P. A., and Berlese, A. N.
(34) 1895. Una nuova malattia del frumento. Riv. di Patol. Veg. 4: 56. Abs. in Hedw. 35: (21); in E. S. R. 7: 410: and in Zeit. f. Pfk. 6: 50.
Sphaeroderma damnosum infests bases of sheaths.

Henning, E.
(35) 1895. Agrikulturbotaniska anteckningar från en resa i Tyskland och Danmark är 1894. Med. f. Kon. Landt. Nr. 11, är 1895 (Nr. 29). 72 S. Abs. in Zeit. f. Pfk. 6 (1896): 234–235.

Cuboni, G.
(36) 1896. Notizie sulle malattie della piante coltivate. Bol. d. Not. Agrar. 18 (No. 36): 487–500.

Briosi, G.
(37) 1896. ———. Bol. d. Not. Agrar. 18 (No. 42): 544–548.

Frank, A. B.
(38) 1896. ———. Jahrb. d. Sondera. f. Pflanzenschutz, Heft 26: 9.
(39) 1897. ———. Jahrb. d. Sondera. f. Pflanzenschutz, Heft 29: 14.

Berlese, A. N.
(40) 1897. Nuovi studi sulla malattia del frumento sviluppatasi nel 1895 in Sardegna. Riv. D. Patol. Veg. 5: 88–97. Abs. in Zeit. f. Pfk. 8 (1898): 102.

Solla
*(41) 1897. Notizen über einige in Italien aufgetretene Krankheitserscheinungen. Zeit. f. Pfk. 7: 159–164.

Prillieux
*(42) 1897. Maladies plantes agricoles, 2: 221.
The lower node turns black and dies. The first internode becomes brown, and black specks appear. All browned parts are invaded by a mycelium.

———

*(43) 1897. Sur le pied noir du blé ou piétin des céréales. Bul. Sta. Agron. Laon, p. 63–66. Abs. in E. S. R. 9: 1057.
The first node is attacked, and the plant falls over. Mild, moist weather is favorable to the disease. Seed and chaff are said to spread the disease.

Lindau, G.
*(44) 1897. Die Natürlichen Pflanzenfamilien (Engler and Prantl's), 1 (1 Teil, Abt. 1): 440.

Frank, A. B.
*(45) 1897. Der Weizenhalmtöter (*Ophiobolus herpotrichus* Sacc.). Kampfbuch gegen die Schädlinge unserer Feldfrüchte, p. 67, pl. 3, fig. 8–11.

Describes disease with blackening of the stem-base and roots.

McAlpine, D.
*(46) 1898. The fungi on the wheat plant in Australia. Agr. Gaz. N. S. Wales, 9: 1009.

"There is no doubt that the fungus [*Cladosporium herbarum*] is found associated with the disease [take-all], as I have never found a case of it without its presence * * * but "until infection experiments have been carried out, it is premature to speak of it as the 'Take-all fungus.'" * * * "This [*O. herbarum*] forms dark-colored blackish-olive patches on both surfaces of the leaf, usually giving it the appearance of being densely spotted." * * * "The conidia are simple or uniseptate * * * occasionally bi- or tri-septate." He lists *Puccinia graminum*, *P. dispersa*, *Ustilago segetum*, *U. bullata*, *Urocystis occulta*, *Septoria glumarum*, *S. graminum*, *Ascochyta graminicola*, *Diplodia olivacea*, *Tilletia tritici*, *Cladosporium herbarum*, *Macrosporium graminum*, *M. cercalium*, *Claviceps purpurcum*, and *Epicoccum neglectum*.

Mangin, L.
*(47) 1898. Sur le piétin ou maladie du pied chez le blé. Compt. Rend. Acad. Sci. Paris, 127 (No. 5): 286–288. Abs. in E. S. R. 10: 650.

Author claims that the parasitism of both Leptosphaeria and Ophiobolus is well established. Ophiobolus is in the lower nodes and on the roots, and is the most important. Other fungi present are saprophytes.

Hollrung, M.
*(48) 1898. Bemerkungen über die im Jahre 1898 zur Kenntniss der Versuchstation für Pflanzenschutz zu Halle a S. gelangten Pflanzenkrankheiten. Jahresber. Vers. Stat. Pflanzenschutz, Halle, 10: 35–64, fig. 3. Abs. in E. S. R. 11: 1057.

*(49) 1898. Das rechtzeitige Pflügen der Stoppeln und sein Einfluss auf gewisse Krankheiten unserer Halmfrüchte. Jahresber. Vers. Stat. Pflanzenschutz, Halle, 10: 29–34. Abs. in E. S. R. 11: 959.

Advises plowing under to control Leptosphaeria and Ophiobolus.

Peglion, V.
*(50) 1898. Il diradamento del grano e dell' avena nell' Agro romange nella Maremma. Stat. Sper. Agrar. Ital. p. 467–484. Abs. in Hollrung's Jahresb. 1:29.

On rye, due to *Ophiobolus herpotrichus* and *O. graminis*.

Frank, A. B.
(51) 1898. ———. Jahrb. d. Sondera. f. Pflanzenschutz, Heft 38:16.

Berlese, A. N.
*(52) 1898. Nuovi studi sulla malattia del frumento sviluppatasi nel 1895 in Sardegna. Bol. di Not. Agrar. Roma, p. 430–437.

A fungus determined as *Sphaeroderma damnosum* was present in foot-rot of grain. This fungus, with its conidial stage, Fusarium, is regarded as a saprophyte which can become a parasite and cause the disease.

Frank, A. B.
(53) 1899. ———. Jahrb. d. Sondera. f. Pflanzenschutz, Heft 50:23.
(54) 1899. Das Auftreten des Weizenhalmtőters auf der Gerste. Deut. Landw. Presse, 26:806, 807. Abs. in Hollrung's Jahresb. 2:45, 227.

Solla
*(55) 1899. In Italien im Jahre 1898 aufgetretene Krankheiten. Zeit. f. Pfk. 9:297–299.

Notes *Ophiobolus graminis*.

Mangin, L.
*(56) 1899. Contribution á l'étude de quelques parasites du blé. Overs K. Danske Vidensk. Selsk. Forhandl. p. 213–272, pl. 3, fig. 17. Abs. in E. S. R. 12:567.

Thinks that Leptosphaeria is the cause of the foot-rot, but it is accompanied by Ophiobolus, Pyrenophora, and other fungi. Claims that cultures prove the Coniosporium to be the conidial form of *Ophiobolus graminis*.

*(57) 1899. Sur le piétin ou maladie du pied du blé. Bul. Soc. Myc. de France, 15:210–237. Abs. in Hollrung's Jahresb. 2:44, 227.

Pyrenophora, Dictyosporium, and Aspergillus are described. Author holds a Leptosphaeria to be the primary cause and the Ophiobolus a secondary cause. Leptosphaeria arises from the superficial mycelium. A Coniosporium belongs to the Ophiobolus. In October, pots of earth were irrigated with water bearing suspension of spores of Leptosphaeria and Ophiobolus. The plants were dead on February 15 from Lepto phaeria. Ophiobolus gave negative results. The roots were black. Leptosphaeria is brown when superficial, hyaline when internal. Attachments were present. Perithecia are free or immersed. Morbid histology is described. Ophiobolus forms flecks, superficial, adherent, distinguished by different attachments.

Bussard, L.
(58) 1899. Le piétin et la verse des céréales. Rev. de Vit. 11:685–687. Abs. in Hollrung's Jahresb. 2:225.
A general discussion of the various views as to the cause of foot-rot.

d'Almeida, J. V.
(59) 1899–1900. ———. Agr. Contemp. Lisboa, 1899 u. 1900. Abs. in Zeit. f. Pfk. 11 (1901):237.

Marenghi.
*(60) 1900. Come possiamo difenderci dall' Ofiobolo? Bol. di Ent. Agr. e Pat. Veg. 7:126. Abs. in Hollrung's Jahresb. 3:206.

Helms, R.
*(61) 1900. Take-all. Jour. Dept. Agr. W. Austral., Feb., p. 30.
A brief description Cause thought to be a fungus.

Eidam
(62) 1900. Erhebungen über das Lagern des Getreides usw. Zeit. d. Landw. Schlesien, p. 1612. Cited by Krüger in (95).

Frank, A. B.
(63) 1900. ———. Jahrb. d. Sondera. f. Pflanzenschutz, Heft. 60:34.
*(64) 1900. Der Weizenhalmtöter. Deut. Landw. Presse, 27 (No. 53):675, pl. 1. Abs. in E. S. R. 12:261, and in Hollrung's Jahresb. 3:205.
Discusses *Ophiobolus herpotrichus*, the results of infection at various ages of the wheat plant, and the influence of various cultural methods.

Kühn
(65) 1900. Der Weizenhalmtöter. Ill. Landw. Zeit. 20:212. Abs. in Hollrung's Jahresb. 3:31.

Frank, A. B.
(66) 1901. ———. Ber. d. deut. bot. Ges. 19, Heft 29.

Delacroix, D.
*(67) 1901. Sur le piétin des céréales. Bul. Soc. Myc. de France, 17:136–144, fig. 1, 2. Abs. in Hollrung's Jahresb. 4:65.
Diseased wheat was replanted in pots. Perithecia were first found in November. Some were of Leptosphaeria, others of Ophiobolus. On some plants both were present. He used sterile soil and seeds in pots and infected them with water holding spores. Three to four months later, traces of disease were present. He concludes that both Ophiobolus and Leptosphaeria can produce the disease. Close sowing increases disease.

Summers, W. L.
*(68) 1901. Wheat-stem killing fungus. Jour. Agr. and Ind. S. Austral. 4: 521.

"There appeared to be a constriction of one or more joints of the plant, and at the base of the stems there were indications, in the form of sooty spores, of a fungus disease. The samples were sent to Mr. D. McAlpine, who states that he finds the wheat attacked by the fungus disease known in Europe as the 'wheat-stem killer' (*Ophiobolus herpotrichus*). This is the first recorded instance of the disease in Australia, though it has probably existed here for some years."

Jungners
(69) 1901. Über die Frostbeschädigung des Getreides im vergangenen Winter und die begleitende Pilzbeschädigung desselben. Zeit. f. Pfk. 11: 343–344.

Mangin, L.
*(70) 1902. Observations sur le piétin du blé. Jour. Agr. Prat. n. ser. 4 (No. 36): 306–308. Abs. in E. S. R. 14: 580, and in Hollrung's Jahresb. 5: 124.

Inoculations were made with watery suspension of spores of Leptosphaeria and Ophiobolus. *L. herpotrichoides* caused disease; Ophiobolus caused disease only rarely, and is secondary.

Nilsson-Ehle
(71) 1902. ———. Sveriges Utsädesförenings Tidskrift, 12: 185–211. Abs. in Hollrung's Jahresb. 5: 116–117.

Remer
(72) 1902. ———. Jahr. d. Schles. Ges. f. vat. Kul. Abs. in Hollrung's Jahresb. 5: 124. (Cf. Zeit. d. Landw. f. Schlesien, 1902, Heft 2; 1903, Heft 23: 723.)

Holds that both Ophiobolus and Leptosphaeria are saprophytes.

Delacroix, G.
*(73) 1902. Maladies des plantes cultivées, p. 8.

Recommends drainage.

McAlpine, D.
*(74) 1902. Take all in wheat. Jour. Dept. Agr. Victoria, 1: 74–80. Abs. in Hollrung's Jahresb. 5: 129.

"The wheat plant makes a start all right, but before the stalk appears the green color fades and the outer leaves become yellow. When the stalk is developed it soon becomes stunted, and never matures the ear. The entire plant soon dies, and this is the case over the affected area. The roots, too, have a very characteristic appearance. They are stunted and deformed at an early stage. * * * The occurrence of the disease in patches is another feature." In many instances the basal portion of the stem was considerably blackened, and on the inner surface of the sheaths the fungus *Ophiobolus*

herpotrichus was found. The roots were often black and dead and covered with black fungous threads. Wheat varieties show but little difference in susceptibility. "Take all largely depends on the nature of the season and the mechanical condition of the soil. * * * If the soil is neither too dry * * * nor so wet as to cake * * * and contains sufficient plant food * * * then the 'Take all' will not appear."

Cordley, A. B.
*(75) 1902. A foot-rot of wheat. Ore. Agr. Exper. Station Rep. p. 66, 67.

Cordley says: "I find that nearly every stalk * * * is infested at the base where it joins the roots, with a fungus disease * * *" It appeared in spots throughout the fields. "The disease is characterized by a blackening of the tissues of the lower part of the stem, particularly at the crown where the roots are given off, and by the stunted, unthrifty appearance * * *" Fungi were present but no spores were found.

In a personal letter dated June 4, 1919, Dean Cordley writes me: "In reply to your letter of May 28, I have made no observations since the 1902 report in regard to the disease in question and have not published anything further along that line."

Peglion, V.
*(76) 1902. Sopra il cosidella brusone del frumento. Staz. Sper. Agr. Ital. 35 (No. 11, 12): 865–886. Abs. in E. S. R. 14: 978, and in Hollrung's Jahresb. 5: 126.

The author believes the disease to be due at times to soil conditions.

Malkoff, K.
(77) 1903. Die schädlichsten Insekten und Pflanzenkrankheiten, welche an den Kulturpflanzen in Bulgarien während des Jahres 1903 geschädigt haben. Abs. in Zeit. f. Pfk. 15 (1905): 52.

Segura, J. C.
(78) 1903. El acame, encamado ó acamado. Bol. Com. de Parasitologia Agr. (Mexico), 2: 62–66. Abs. in Hollrung's Jahresb. 7 (1904): 98.

Stift
(79) 1903. Die im Jahre 1902 beobachteten Schädiger * * * landw. Kulturpflanzen, Oesterreich-ungar. Zeit. f. Landw. Bd. 2.

Marchal
*(80) 1903. Die im Jahre 1902 in Belgien beobachteten Pilzkrankheiten. Zeit. f. Pfk. 13: 216.

Mentions Ophiobolus on wheat.

Kornauth, K.
(81) 1903. Pathologische Vorkommnisse en Österreich-ungarn. Abs. in Zeit. f. Pfk. 14 (1904): 353.

Summers, W. L.
*(82) 1903. "Takeall" and "whiteheads" in wheat crops. Jour. Agr. and Ind. S. Austral. 7 (No. 5): 297–299. Abs. in E. S. R. 15: 687.

Advises burning stubble prior to plowing. "There is little doubt that what has often been called 'Takeall' was simply root fail, caused by a dry, hollow seed bed."

Van Hall, C. J. J.
(83) 1903. Notes on the wheat stem disease (*Ophiobolus herpotrichus*). Tijdschr. Plantenzieken, 9: 77–110. Abs. in E. S. R. 16: 571, and in Hollrung's Jahresb. 6: 78.

Notes disease in Holland. Fungus lives in soil. Discusses relation to rotation.

McAlpine, D.
*(84) 1904. Take all and white heads in wheat. Jour. Dept. Agr. Victoria, 2: 709. Abs. in Hollrung's Jahresb. 6: 77.

He says "it [take-all] is now proved through investigation of this branch to be due to a fungus." * * * "True take all * * * had invariably a special fungus at the butt of the stem or on the roots * * * so that the term [take-all] has now a definite meaning and applies to wheat plants which have succumbed to the attacks of this particular fungus." Diseased stubble was placed in sand in pots and wheat planted in the pots with it. "After eighteen days * * * characteristic brownish spots were observed on the young stems. * * * Microscopic examination showed the presence in abundance of the young mycelium of the Ophiobolus. After six weeks many of the plants were dead."

In December, 1900, samples of white head were sent to McAlpine, and he says that he determined the fungus responsible for white heads and take-all.

*(85) 1904. Take all and white heads in wheat. Bul. 9, Dept. Agr. Victoria; Jour. Dept. Agr. Victoria, 1904, p. 410–426.

Ophiobolus is noted on *Bromus sterilis* and a sterile mycelium on *Agropyron scabrum*.

Brizi, A.
(86) 1904. Il "mal del piede" del frumonto e l'abbruciamento delle stoppie. Avven. Agric. 12: 147–153.

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(87) 1904. Wheat fungus (*Ophiobolus graminis*). Jour. Bd. Agr. (London) 11: 154, 155. Anonymously cited in Hollrung's Jahresb. 7: 99.

Pòsch-Grinàd, K.
*(88) 1904. Mycopathologisches aus Ungarn. Zeit. f. Pfk. 14: 158.

Mentions Ophiobolus on wheat.

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*(89) 1906. Takeall in wheat. Jour. Dept. Agr. S. Austral. 10 (No. 5): 280–283. Abs. in E. S. R. 18: 947.

Thirty per cent. injury is reported in some fields.

Kirchner, O.

*(90) 1906. Die Krankheiten und Beschädigungen unserer landwirtschaftlichen Kulturpflanzen, p. 33–34, 81.

The disease followed weakening of the plant from other causes, as spring frost, poor nutriment, too much water, etc. Ophiobolus is perhaps not a true parasite.

Appel

(91) 1906. Untersuchungen über die Gattung Fusarium. Ber. a. d. Biol. Anst. f. Land. u. Forstw.

Hiltner, L.

(92) 1906. ———. Ber. Kgl. Bayer. Agr. Anst. München, p. 50.

Robinson, G. H.

*(93) 1907. Take all and its control. Jour. Dept. Agr. Victoria, 5 (No. 4): 253–256. Abs. in E. S. R. 19: 151, and in Hollrung's Jahresb. 10: 105.

A dry summer following a wet winter is most favorable to the disease. The butts are quite black and perithecia occur in the sheaths.

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(94) 1907. ———. Heft 6? Bericht über die Tätigkeit der Kaiserl. Biologischen Anstalten in Jahre 1907: 11. As cited in Ill. Land. Ztg. 33 (No. 65): 589.

Krüger, F.

*(95) 1908. Untersuchungen über die Fusskrankheit der Getreides. Arb. K. Biol. Anst. f. Land. u. Forstw. 6 (No. 3): 321–351, pl. 1. Abs. in E. S. R. 22: 148, and in Hollrung's Jahresb. 11: 127, 137.

Author holds that while Leptosphaeria and Ophiobolus do cause disease as facultative parasites they are not the immediate cause of the trouble, which arises from weakening of the wheat by rain, frost, etc. Inoculation experiments were made with Leptosphaeria, Dictyosporium, Ophiobolus, Hendersonia, Coniosporium, and Fusarium. *Leptosphaeria herpotrichoides* was found on rye and wheat; *Ophiobolus herpotrichus* on rye, wheat, and barley.

Störmer, K.

*(96) 1908. Die in der Provinz in Sommer 1908 beobachteten Krankheiten aus Getreide. Landw. Wchnschr. Sachsen. 10 (No. 35): 306–309; No. 38: 331, 332; No. 39: 340, 341; No. 40: 347–349. Abs. in E. S. R. 20: 1042.

Author regards the cause of the disease as still in doubt.

Lindau, G.
*(97) 1908. Die pflanzlichen Parasiten. Sorauer's Handbuch d. Pflanzenkrankheiten, 2:256.

Places Ophiobolus in the Pleosporaceae. *O. graminis* was first known in France; then in Belgium and Saxony. The wheat is normal till bloom-time, when it wilts and dies suddenly. *O. herpotrichus* Sacc. has spores double the length of *O. graminis*. Apparently infection comes at germination. Wet soil and fertilizers favor infection. Early varieties are least resistant. Known also in Italy, Germany, and Holland. Coniosporium is suggested as an imperfect form.

Dombrovski, N.
(98) 1909. [Fungi as a cause of the lodging of cereal crops.] Khozyaistvo, 1909:334, 335. Abs. in Zhur. Opuitn. Agron. (Russ. Jour. Expt. Landw.) 10 (No. 4):558; and in E. S. R. 23:546.

Shows, as he believes, that *Ophiobolus graminis* is the cause of the lodging, and emphasizes value of drainage to prevent loss.

Farrelly
*(99) 1909. Takeall. Abs. in Jour. Agr. S. Austral. 13:272.

Massee, G.
*(100) 1910. Diseases of cultivated plants and trees, p. 226–227. Macmillan, N. Y.

Ophiobolus graminis kills plants when young, and produces either "take all" or "whitehead". Description of stages given. The root and stem-base are attacked. A brown superficial mycelium is present on surface of stem and leaf sheaths, forming a weft or felt. Perithecia in winter form on this felt. The disease is also found on Agropyron, Bromus, and oats in Europe, England, and Australia. *O. herpotrichus*, of the same general appearance, is recorded in Italy.

Mortensen, M. L., Rostrop, S., and Ravn, F. K.
(101) 1910. Oversigt over Landbrugsplanternes Sygdomme i 1910, No. 27. Abs. in Zeit. f. Pfk. 22:358.

Notes foot-rot in Denmark. Chiefly due to Fusarium.

Reynolds, M. H.
*(102) 1910. Some conditions qualifying success in the production of wheat in central and western districts. Dept. Agr. N. S. Wales, Farmers' Bul. 42:128.

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(103) 1910. ———. Heft 11, Bericht über die Tätigkeit der Kaiser. Biologischen Anstalten in Jahre 1910:19. Cited in Ill. Land. Ztg. 33 (No. 65):589.

Neldner, Heinrich, et al.
*(104) 1910. Takeall. Editor's note of discussion, Jour. Agr. S. Austral. 13:537–538.

Lehmann, et al.
*(105) 1910. Takeall in wheat. Note of the discussion, Jour. Agr. S. Austral. 13:544.

Johns
*(106) 1910. Does takeall live in the soil from one year to another? If so, what are the best means of treatment? Jour. Agr. S. Austral. 13:701–702.
*(107) 1910. Takeall. Abs. in Jour. Agr. S. Austral. 14:85.

Pedler, Martin, and Paterson
*(108) 1910. Takeall. Editor's report of the discussion, Jour. Agr. S. Austral. 14:186–187.

Westbrook
*(109) 1910. Takeall. Editor's abstract, with notes of discussion, Jour. Agr. S. Austral. 14:422–423.

Hill
*(110) 1910. Takeall: cause and cure. Jour. Agr. S. Austral. 14:423–424.

Richardson, A. E. V.
*(111) 1910. "Takeall." Jour. Agr. S. Austral. 14:466–471. Abs. in E. S. R. 24:551, and in Hollrung's Jahresb. 13:148.
The crop promised well till October, then the disease became so serious as to reduce the yield to one bushel per acre. Oats near-by were free of disease. Disease occurred in patches. One to two inches of lower stems were blackened with the growth of the fungus. A good stubble-burn gives disease-free crops. Advises to fallow early and to follow with oats.

Pridham, J. T.
*(112) 1911. Field experiments with wheat diseases. Jour. Dept. Agr. Victoria, 9:250–255.
Burning stubble is beneficial. Oats are good in rotation, though a similar disease has been noted in oats and barley. A Helminthosporium was found, but Pridham does not think it responsible for the disease.

Sutton, G. L.
*(113) 1911. Take all. Practical methods for its eradication and control (*Ophiobolus graminis*). Agr. Gaz. N. S. Wales, 22 (No. 2):161–163. Abs. in E. S. R. 25:44.
Advises clean fallowing and rotation.

Journal of Agriculture of S. Australia
*(114)) 1911. Samples of growing crops and takeall. Jour. Agr. S. Austral. 14:809–810.

Lowrie, Richardson, et al.
*(115) 1911. Takeall. Abstract of discussion, Jour. Agr. S. Austral. 14:884.

Nicholls, R., et al.
*(116) 1911. Takeall. Abstract of discussion, Jour. Agr. S. Austral. 14: 899.

Correll
*(117) 1911. Takeall. Abs. in Jour. Agr. S. Austral. 14: 902.

Fogarty
*(118) 1911. Takeall. Abs. in Jour. Agr. S. Austral. 14: 995.

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*(119) 1911–12. L'Ofiobolo o mal del piede del frumento. Ann. d'Uffio. Agr. Prov. Bologna, 18: 194–197. Abs. in E. S. R. 30: 349.

Brief account of this disease; attributed to *Ophiobolus graminis* and *O. herpotrichus*.

Fron, G.
*(120) 1912. Contribution à l'étude de la maladie "Pied noir des céréales" ou "Maladie du Piétin". Ann. Sci. Agron. 4 (ser. 1, No. 1): 3–29, fig. 3. Abs. in Internat. Inst. Agr. (Rome), Bur. Agr. Intel. and Plant diseases, 3 (No. 4): 1054–1056; in E. S. R. 27: 747; and in Hollrung's Jahresb. 15: 149.

Sterile wheat was easily infected with Leptosphaeria.

Eriksson, J.
*(121) 1912. Fungoid diseases of agricultural plants. London.

Black cover on the lowest joint. Roots black for most of their length. Conidia (Coniosporium) small, ovate, one-celled.

Bruck, W. F.
*(122) 1912. Plant diseases, p. 47.

Ophiobolus herpotrichus on wheat; *Leptosphaeria herpotrichoides* on rye.

Mangin, L.
*(123) 1912. Le piétin ou maladie du pied noir du blé. Jour. Agr. Prat. n. ser. 24 (No. 32): 174–176, fig. 3. Abs. in E. S. R. 27: 748, and in Hollrung's Jahresb. 15: 135, 151.

Ophiobolus and Leptosphaeria present. Mycelium brown, sterile. The Leptosphaeria is the most important.

Averna-Sacca, R.
*(124) 1912. Relatorio do gabinete de pathologia vegetal. Bol. Agr. 13 (No. 3): 235–236, fig. 6. São Paulo. Abs. in E. S. R. 29: 243.

Describes foot-rot but does not definitely state that it occurs in Brazil.

Bureau of Microbiology
*(125) 1912. "Take all" in wheat. Agr. Gaz. N. S. Wales, 23 (No. 11): 934–936. Abs. in E. S. R. 28: 646.

Mycelium abundant in the leaf sheaths. Plant dies from below upwards. No spores.

Hiltner, L
*(126) 1912. Eine Voraussage! Im heurigen Jahr wird die sogenannte Fusskrankheit des Getreides in Stärkerem Masse auftreten. Prak. Blatter f. Pflanzenbau und Pflanzenschutz München, 10: 37–45. Abs. in Hollrung's Jahresb. 15: 150.

Claims that unripe seed or seed-wheat grown in an abnormally dry season produced very susceptible plants, and that infection is seed-borne.

Massee, G.
*(127) 1912. White heads or take all of wheat and oats. Bul. Misc. Inform. Roy. Bot. Gard. Kew, 10: 435–439, fig. 1; Jour. Bd. Agr. 19 (No. 12): 1020–1025, pl. 1. 1913. Abs. in E. S. R. 28: 646.

Two or three inches of straw at base blackened as though charred. Roots woolly, owing to root hairs. *Ophiobolus graminis* is readily recognized by the dark color of its mycelium, which forms a thin felt on the stem and leaf sheaths. Says the disease is well known in Italy, France, Germany, Belgium, Australia, and the United States. In hanging drop the colored mycelium gives rise to a hyaline mycelium.

Peglion, Vittoria
*(128) 1912. Intorno al mal del piede del frumento. Casale. Stab. tip. ditta C. Cassone. 60 p.

Störmer, K., and Kleine, R.
*(129) 1912. Über das auswintern des Weizens und das auftreten der Fusskrankheit. Illus. Landw. Ztg. 32 (No. 38): 360–361. Abs. in E. S. R. 28: 52, and in Hollrung's Jahresb. 15: 135, 153.

Ophiobolus herpotrichus and *Typhula graminum* caused disease following severe cold; the latter noted heretofore only in Sweden and Denmark.

Voges, E.
*(130) 1912. Zur Fusskrankheit des Getreides. Deut. Landw. Presse, 39 (No. 71): 815, 816, fig. 4; No. 72: 823, 824, fig. 3. Abs. in E. S. R. 28: 445.

Concludes that fungi are *not* the primary cause of foot-rot, but that it is due to lowering of vitality by cold or drouth.

Schaffnit, E.

*(131) 1912. Der Schneeschimmel und die übrigen durch *Fusarium nivale* Ces. hervorgerufenen Krankheitserscheinungen des Getreides. Landw. Jahrb. 43: 521–648. Abs. in Hollrung's Jahresb. 15: 137–140, 55.

Discusses extensively a disease attributed to *Fusarium nivale*, one phase of which is a foot-rot.

(132) 1912. Beiträge zur Biologie der Getreidefusarien. Jahrb. d. Ver. ang. Bot.

Rasquin, Max

*(133) 1912. Le piétin des céréales. Jour. Soc. Agr. Brabant and Hainaut, 58: 421–422. Oct. 11, 1912.

Summarizes earlier literature.

Bredemann, G.

(134) 1912. Das diesjährige starke Auftreten der Fusskrankheit und der Schwärze des Getreides in unseren Bezirk. Amt. d. Land. f. Reg. Cassel, 16: 412. Abs. in Hollrung's Jahresb. 15: 148.

Ivett, J.

*(135) 1912. Takeall and how to control it. Jour. Agr. S. Austral. 16: 84–85.

Reuter, E.

(136) 1912. Ett uppträdande af halmdödaren (Ophiobolus) i Finland. Med. af Soc. Fau. et Fl. Fennica, 38: 65. Abs. in Hollrung's Jahresb. 15: 152.

Depole, R., and Voglino, E.

(137) 1912. [Foot-rot of grains.] Coltivatore, 58 (No. 18): 567–572, fig. 2. Abs. in E. S. R. 27: 748.

Prunet, A.

*(138) 1913. Sur les champignons qui causent en France le piétin des céréales. Compt. Rend. Acad. Sci. Paris, 157 (No. 22): 1079–1081. Abs. in E. S. R. 30: 648.

This disease is of importance in parts of Italy.

Guerrapain, A., and Demolon, A.

*(139) 1913. Enquête et observations sur la maladie du piétin des céréales. Jour. Agr. Prat. 137: 566–567, 627–630.

Discusses climatic influences, calling particular attention to increase of this disease following a mild winter, to geographic distribution, to time and density of seeding, to varietal resistance, to fertilizers, and to the use of copper sulfate. It occurs on rye and winter barley. Abnormal winter temperatures favor the disease.

*(140) 1913. Enquête sur la maladie du piétin. Betterave, 23 (No. 597): 386–388, fig. 1; No. 598: 402–405; 24 (No. 599): 7, 8. Abs. in E. S. R. 30: 747.

Either high winter temperatures or excessive growth of the wheat favors development of the disease.

Eriksson, J.
*(141) 1913. Die Pilzkrankheiten der Kulturpflanzen, p. 138–140. (Cf. No. 121.)

Great Britain Board of Agriculture
*(142) 1913. "White heads" or "take-all" of wheat and oats. (*Ophiobolus graminis* Sacc.) Jour. Gt. Brit. Bd. Agr. 19:1020–1025. Reprinted with slight changes and abridgment as Leaflet 273 (July, 1913) by Gt. Britain Bd. Agr. and Fisheries, 1 fig. Abs. in E. S. R. 30:148.

Voges, E.
*(143) 1913. *Ophiobolus herpotrichus* und die Fusskrankheit des Getreides. Ztschr. f. Gärungsphysiol. 3 (No. 1):43–83, fig. 5. Abs. in E. S. R. 31:542.

The fungus appears as a felty layer over the host, and in dampness develops *Fusarium rubiginosum* A. & W. Ascospores give two kinds of mycelium: (1) a dark thick-walled one; (2) a hyaline thin one. The second gives the Fusarium. No. 1 put on cooked wheat gives Fusarium; and on raw wheat, the usual dark mycelium. The mycelium of Ophiobolus, *Cladosporium herbarum*, or *Mucor racemosus* may be present. The Fusarium form is most dangerous.

*(144) 1913. Die Schneeschimmel. Deut. Landw. Presse, 40 (No. 19):229–231, fig. 3. Abs. in E. S. R. 29:244.

Thinks Fusarium is the conidial form of *Ophiobolus herpotrichus*.

*(145) 1913. Die Witterung und die Fusskrankheit des Getreides. Deut. Landw. Presse, 40 (No. 83):993, 994, fig. 3. Abs. in E. S. R. 30:541.

Indicates that fungi other than Ophiobolus may cause foot-rot, and that Ophiobolus and Leptosphaeria are not the primary cause of the disease. The conidial form of Ophiobolus is given as Acremonium.

Journal of Agriculture of S. Australia
*(146) 1913. Takeall. Abs. in Jour. Agr. S. Austral. 16:1430.
*(147) 1913. Wheat diseases. Abstract of discussion at Annual Conference meeting, Jour. Agr. S. Austral. 17:178–180.

Trowbridge, J., et al.
*(148) 1913. Takeall. Abs. in Jour. Agr. S. Austral. 17:206–207.

McCormack, L.
*(149) 1913. Takeall. Abs. in Jour. Agr. S. Austral. 17:247.

Hartmann, A.
*(150) 1913. Takeall. Extract in Jour. Agr. S. Austral. 17:249–250.
*(151) 1913. Takeall. Extract in Jour. Agr. S. Austral. 17:551.

Gray, J.
*(152) 1913. Takeall and oats. Extract in Jour. Agr. S. Austral. 17: 631–633.

Stebler, F. G.
(153) 1913. [Plant protection.] Land. Jahr. Schw. 27:18 Abs. in E. S. R. 29: 150.

Notes presence of foot disease due to Ophiobolus.

Reuther
(154) 1913. [Foot disease of wheat.] Deut. Landw. Presse, 40: 780. Abs. in E. S. R. 30: 243.
*(155) 1913. Beobachtungen über die Fusskrankheit des Weigens. Ill. Land. Ztg. 33: 589.

Notes on *Ophiobolus herpotrichus*, on *Hordeum murinum*, *Bromus sterilis*, *Festuca bromoides*, and *Triticum repens*. Foot-rot is worst when frost injury occurs in fields that are infected with foot-rot fungi.

Robert, E.
*(156) 1913. Quelques mots encore sur le piétin du blé. Jour. Agr. Prat. 137: 715–716.

Mentions five conditions of maximum disease and deduces five recommendations as to practice.

Boijeau, A.
*(157) 1914. Le piétin du blé. Prog. Agr. et Vit. 61: 241–247. Abs. in E. S. R. 31: 51.

Author discusses the influence of environment and variety on prevalence of foot-rot.

Mangin, L.
*(158) 1914. La question du piétin. Jour. Agr. Prat. n. ser. 27 (No. 8): 236–239, 267–269. Abs. in E. S. R. 31: 147.

Fusarium nivale, *F. hibernan*, *F. minimum*, *Nectria graminicola*, and *Calonectria nivalis* are discussed. Infection is said to be by either soil or seed. In piétin the stems are black; the grain is weak and lodges. Secondary fungi are Septoria, Sphaerella, Helminthosporium, Cladosporium, Leptosphaeria, etc.

Foëx, E.
(159) 1914. [Stalk disease of wheat.] Bul. Soc. Path. Veg. France, 1 (No. 1): 26–30, pl. 1. Abs. in E. S. R. 37: 248.

Ophiobolus graminis is said to work at the base of the stalk; *Leptosphaeria herpotrichoides* higher on the stem. *Cercosporella herpotrichoides*, perhaps a conidial form of Leptosphaeria, is also said to cause a weakening of cereal stems.

Hollrung, M.
*(160) 1914. Die Mittel zur Bekämpfung der Pflanzenkrankheiten, p. 292.

Emphasizes drainage, quoting Dombrovski—(98) of this list.

Berthault, P.
*(161) 1914. Contribution à l'étude du piétin des céréales pendant l'année 1913. Rev. Gen. Bot. 25: 29–34. Abs. in E. S. R. 32: 641.

Voges, E.
*(162) 1914. [The conidial form of *Ophiobolus herpotrichus.*] Centralbl. Bakt. [etc.]. Abt. 2, Bd. 42 (No. 1–4): 49–64, fig. 9. Abs. in E. S. R. 32: 843.

Finds *Hendersonia herpotricha*, Ascochyta, Septoria, Mucor, Leptosphaeria, Cladosporium, and *Alternaria tenuis* associated with Ophiobolus.

Ross, H.
*(163) 1915. Wheat culture. Dept. Agr. N. S. Wales, Farmers' Bul. 101.

Goldsworthy, W. R.
*(164) 1915. Takeall. Extract in Jour. Agr. S. Austral. 18: 921.

Journal of Agriculture of S. Australia
*(165) 1915. "Take-all". Jour. Agr. S. Austral. 18: 966.

Perkins, Arthur J.
*(166) 1915. What the man on the land wants to know. Jour. Agr. S. Austral. 18: 1072–1080.

Replies to a series of questions.

Darnell-Smith, G. P., and Mackinnon, E.
*(167) 1915. Fungous diseases of wheat. Dept. Agr. N. S. Wales, Farmers' Bul. 102: 3–31, fig. 28. Abs. in E. S. R. 34: 845.

Notes the disease on barley, barley-grass, and Bromus. It occurs on oats in England and N. S. Wales.

Capus, J.
*(168) 1915. Action de l'acide sulfurique sur le "piétin" du blé. Compt. Rend. Acad. Agr. France, 1: 228–231. Abs. in E. S. R. 34: 244.

Describes accurately three phases in the development of the disease which he considers due to Leptosphaeria. Reports beneficial effect of sulfuric acid.

(169) 1915. Action de l'acide sulfurique sur le piétin du blé. La Vie Agricole et Rurale, No. 4.

Possibly identical with *(168).

Moretlini, A.
*(170) 1915. L'impiego dell' acido sulforico per combattere le erbe infeste nel frumento. Staz. Sper. Agr. Ital. 48: 693–716. Abs. in E. S. R. 36: 534.

Biffen, R. H.
*(171) 1915. ———. Jour. Roy. Agr. Soc. Eng. 76:309.
Leptosphaeria culmifruga produces brittleness of stems.

(172) 1916. ———. Jour. Roy. Agr. Soc. Eng. 77:218–220. Abs. in E. S. R. 39:452.

Darnell-Smith, G. P.
*(173) 1916. Green vitriol (ferrous sulfate) as a preventive of take-all. Agr. Gaz. N. S. Wales, 27 (No. 2):134. Abs. in E. S. R. 35:750.
Recommended fifty pounds per acre.

Spafford, W. J.
*(174) 1916. "Bunt" and "Take-all". Jour. Agr. S. Austral. 19: 953–961.
*(175) 1917. Some diseases of wheat crops and their treatments. Jour. Agr. S. Austral. 20:537–548. Abs. in E. S. R. 38:48.
Finds on the roots many dark brown threads. A plate mycelium between sheath and stem is continuous with the root mycelium. This peels off in flakes when dry. Also between sheath and stem a brown band passes upward. Perithecia occur on roots or sheaths. Infection is mainly from the soil. Prevention: burn stubble, kill weeds, use oats. Oats are but little susceptible. Mechanical condition of the soil is very important.

Tanaka, I. T.
*(176) 1917. New Japanese fungi. Notes and translations. Mycologia 9 (No. 3):167–172. Abs. in E. S. R. 38:648.
Ophiochaeta graminis causes diseases on rice.

Godfrey, G. H.
*(177) 1918. *Sclerotium rolfsii* on wheat. Phytopathology, 8 (No. 2):64–66, fig. 1. Abs. in E. S. R. 39: No. 9.
Small brown lesions occurred on the crown.

Pridham, J. T.
*(178) 1919. Take-all, the wheat-growers' worst enemy. Agr. Gaz. N. S. Wales, 30:77–79.
"Whether the disease is caused by the fungus *Ophiobolus herpotrichus*, by *Cladosporium herbarum*, by *Fusarium rubiginosum*, or by *Mucor racemosus*, the result is much the same on the wheat plant." * * * "The roots are rotten."

Brittlebank, C. C.
*(179) 1919. Green manurial crops and "take all". Victoria Jour. Agr. 17:171–174.
Says that McAlpine (84) clearly showed that the disease is due to *Ophiobolus graminis*.

Johnson, A. G.
*(180) 1919. New wheat disease. Extension Messenger for Apr. 30, 1919, 2 (No. 18): 2.

In telegram to J. B. Haberkorn, says that "disease in wheat * * * is almost certainly the serious Australian disease known as take-all, not previously found in America."

Haskell, R. J.
*(181) 1919. Take-all and flag smut: two serious wheat diseases new to the United States. Plant Disease Surv. U. S. Dept. Agr. (A leaflet, without number or date.)

"Take-all, known for many years in Australia and Europe, and flag smut, common in Australia, India, and Japan, have recently been discovered in the United States in the very center of the winter wheat area." * * * "This examination showed the disease to be very similar to the take-all of Australia and Europe, and [it] is probably identical with it."

Lyman, G. R.
*(182) 1919. "Take all" of wheat in this country. Circular letter bearing date of May 1, 1919.

"A serious wheat disease which appears to be the same as the Australian 'Take all' (Ophiobolus) has made its appearance in southern Illinois." * * * "It appears, therefore, that we now have 'take all' in this country."

Johnson, A. G.
*(183) 1919. [As reported at the St. Louis Conference (May 12, 1919) on Take-all and Flag Smut of Wheat.]

"* * * After careful study he decided that the trouble was the Australian 'take-all' disease. Dr. N. A. Cobb, of the U. S. Department of Agriculture, who has seen this disease in Australia, was consulted and stated that the behavior of the disease as described in Illinois agreed perfectly with conditions in Australia. It therefore seemed practically certain that the trouble in Illinois was the Australian 'take-all.'" * * * "Approximate number of acres affected, 802."

Lyman, G. R.
*(184) 1919. Plans for survey of "take-all" and "flag smut" of wheat. Circular letter, dated May 23, 1919.

"In addition to the Madison county area in Illinois, take-all has been found in Porter, Laporte, Tippecanoe, and Jasper counties, Indiana."

Onondaga County Farm Bureau News [N. Y.]
*(185) 1919. New wheat diseases. Onondaga Co. Farm Bur. News, June, 1919.

"Two new wheat diseases, known as 'take-all' and 'flag smut', which have caused serious loss in Australia, have recently been found in Illinois and Indiana."

Bulletin of the American Steel and Wire Co.

*(186) 1919. [Popular description of take-all.] See said Bulletin for June, 1919.

Federal Horticultural Board

*(187) 1919. Notice of public hearing of proposed European quarantine on account of the flag smut and take-all diseases of grains and the wheat nematode or eelworm disease. Mimeographed notice issued June 18, 1919, by U. S. Dept. Agr., Fed. Hort. Bd.

The Secretary of Agriculture is said to have information that "take-all (*Ophiobolus graminis*)" has been "determined as existing * * * in Indiana and Illinois."

U. S. Department of Agriculture

*(188) 1919. Quarantine on account of flag smut and take-all diseases. Notice of Quarantine No. 39 (with regulations). 6 pp.

ARTICLE X.—*The European Corn-borer and some Similar Native Insects.* BY WESLEY P. FLINT AND JOHN R. MALLOCH.

The recent discovery in the eastern part of this country of the European corn-borer (*Pyrausta nubilalis* Hübner) and the possibility of its spread westward, has caused much alarm among farmers throughout the corn belt. The present publication is intended to give a few of the more important facts concerning this insect and some of the closely related native borers, and to supply a means of distinguishing them.

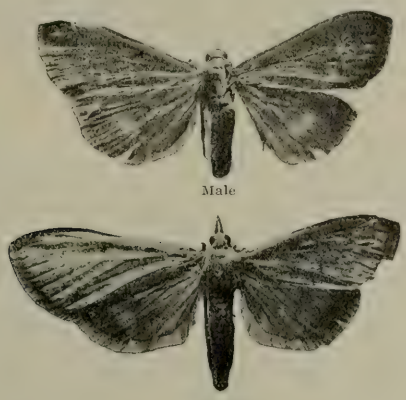


FIG. 1. European corn-borer (*Pyrausta nubilalis* Hueb.). Twice natural size.

DISCOVERY OF THE CORN-BORER AND AREA INFESTED

This borer was first discovered in this country in a field of corn near Boston, Mass., during the summer of 1917. It had probably been imported from Europe in shipments of broom-corn some eight or ten years before. In January of 1919 it was found near Schenectady, N. Y., and late in the summer of 1919 in some of the lake counties in western New York.

It has spread quite rapidly in Massachusetts since it was first discovered, and at present an area of about nineteen hundred square miles in the eastern part of the state is known to be infested, together with a few towns just over the line in New Hampshire. In New York there is an infestation of several hundred square miles in the vicinity of Schenectady, and a still larger area in the western part of the state in the counties bordering Lake Erie.

Injuries

In Europe this insect periodically causes serious losses of corn, hops, millet, and hemp, and is known to feed on many other plants. There are records of destruction of 50 per cent. of these crops during years when the borers were abundant.

In this country the insect is already known to feed on over a hundred different plants, including nearly all of our cultivated crops. Corn is apparently preferred to all other plants, and is the most seriously damaged. The larva feeds on all parts of the plant above ground, including the leaves, stalk, tassel, stem of the ear, and ear. As many as 117 borers have been found in a single stalk of corn, and 15 in a single ear.

From our present knowledge of this insect, it is one of the most destructive which has ever been brought into this country, and seems capable of greater injury to corn than any of our native species.

Life History

The corn-borer passes the winter in the stems of its food plants as a nearly full-grown caterpillar. Nearly all the caterpillars remain in the stem above ground, but they are sometimes found below the surface where the larger parts of the stalk extend into the ground. They remain in a dormant condition until the weather becomes warm in spring, when a small percentage of them feed a little on the dry plants in which they passed the winter. All shortly change to the pupal or resting stage, and in the vicinity of Boston emerge as moths about May 15. The moths have a wing expanse of a little over an inch, with yellow or yellowish red wings (Fig. 1) marked by irregular dark lines. They live from six to thirty-five days, and after mating the females deposit their eggs in small irregular masses, cemented together, on the leaves of their food plants (Fig. 2). Each mass contains from five to fifty or more glistening white eggs. Each moth lays from two hundred to eight hundred eggs, the number laid by moths of the first generation being somewhat smaller than that of the second. The eggs hatch in from five to ten days. The small caterpillars feed externally for a short time and then enter the stems and the larger parts of the leaves (Fig. 3). They complete their growth in from thirty-five to sixty days, pupate in their food plants, and, in Massachusetts, emerge again as moths during July and August. These lay their eggs in the same manner as the first generation, and the

FIG. 2. Egg-mass of European corn-borer on leaf of corn; natural size...

FIG. 3. Corn plants showing the characteristic breaking over of the tassel caused by the work of the European corn-borer.

caterpillars hatching from them become full-grown on the approach of cold weather and hibernate in the stems of their food plants. Although there are two full annual generations of the insect in the Massachusetts area, there is only one in New York, owing, no doubt, to the colder climate. There would certainly be two generations in Illinois, and possibly three in the southern part.

FIG. 4. Ear of corn infested by European corn-borer, showing the characteristic exudations of frass.

MEANS OF SPREAD

The moths are fairly strong fliers, and have been observed to fly over two hundred and eighty-seven yards at a single flight; and as such flights are frequent, it would be easy for the insect to travel a considerable distance during the three or four weeks of its active life as a moth. It has, however, probably been established in new localities mainly while in the larval stage in the stems of its food plants. There is great danger of carrying it in this way from the infested territory, especially in shipments of broom-corn, hemp, celery, corn on the ear, etc., and more particularly in shipments of unshelled seed-corn. During the last few years large amounts of sweet corn on the ear have been shipped from points in the New England States near the known infested territory to canning factories located throughout the Middle Western States (Fig. 4); and perhaps the greatest danger of introducing the pest in the corn

belt has come from these shipments. Any one knowing of such shipments having been made in the last two or three years should notify the Natural History Survey, Urbana, Ill., of fields where such shipments have been planted, and should keep a sharp lookout for the borer in their vicinity, or more particularly in the neighborhood of places where such corn may have been shelled, if there is any likelihood that all the cobs have not been burned, as the borers would probably be transported inside the cobs. Careful examinations have already been made in the vicinity of all canning factories where such corn was known to have been received, but so far no trace of the insect has been found in Illinois.

Means of Control.

At present no very effective means of controlling this insect are known. In fact, the only way by which its numbers may be appreciably reduced is by burning the plants in which it passes the winter. This is a very expensive operation, as the borers are found in the stems of practically all weeds, large grasses, and cultivated crops remaining on the ground after harvest, all of which must be completely burned up. This method of control was put to a thorough test in the infested areas in New York and Massachusetts last year, with the result that the cost of clearing ordinary corn-stubble fields or land used for general truck crops was from $25 to $50 or more per acre. More extensive experimental work along this line is being done with improved machinery in Massachusetts this season (1919), and it is hoped to reduce materially the expense of this method of control. No adequate summer measures have been worked out. Spraying of food plants with arsenicals, while it affords some measure of control, does not kill a sufficiently large percentage of the borers to make it worth while.

Native Borers closely resembling the European Corn-borer

There are several related species which closely resemble the European corn-borer, both in the appearance of all stages of the insects and in their work. The most abundant of these is commonly known as the smartweed-borer (*P. obumbratilis*), which is found very commonly in smartweed throughout the entire state. The life history of this insect is approximately the same as that of the European corn-borer, there being two generations, the moths appearing in May and again the latter part of July, and the insect passing the winter as a full-grown larva in the stems of its food plants. Until the last two or three years, this insect was not generally known to infest corn, but investigations made during the past year have shown that it frequently winters in the corn plant. A single specimen was found in green corn growing in a very large patch of smartweed about July 1, 1919. This specimen, however, had evidently gone to the corn from a newly mown patch of smartweeds,

and simply made a small hole near the base of the corn-stalk in which to pupate. Early in the fall of 1919 examinations carried on throughout the state showed that this borer commonly leaves the smartweed early

FIG. 5. Larvae of the smartweed borer (*Pyrausta obumbratilis* Lederer) in stems of Amaranthus (left) and corn (right).

in fall, where the infestation is heavy, and migrates to corn (Fig. 5) and a number of other plants. We have never taken it in corn where the corn was growing more than thirty feet from infested smartweed. It apparently does no injury whatever to the corn, simply boring a small gallery in the stalk in which to pass the winter, and it does not enter

the corn plant until the ear is fully matured—in fact, generally not until the stalk is quite dry. Up to the present time this borer has been found in the fall in the stems of the following plants:

Smartweed.....*Polygonum hydropiper* L.
Ragweed.....*Ambrosia artemisiifolia* L.
Giant ragweed.....*A. trifida* L.
Indian mallow.....*Abutilon theophrasti* Medic.
Jimson-weed.....*Datura stramonium* L.
Goldenrod.....*Solidago* sp.?
Lamb's-quarters.....*Chenopodium album* L.
Barnyard grass.....*Echinochloa crus-galli* Beauv.
Foxtail grass.....*Setaria glauca* Beauv.
Cocklebur.....*Xanthium spinosum* L.
Western tickseed sunflower. *Bidens aristosa* Britton
Common sunflower.....*Helianthus annuus* L.
Rough pigweed.....*Amaranthus retroflexus* L.
Tumbleweed.....*A. graecizans* L.
Prostrate pigweed.....*A. blitoides* Wats.
Spanish needles.....*Bidens* sp.?
Wild lettuce.....*Lactuca canadensis* L.
Evening primrose.....*Oenothera biennis* L.
Field corn.
Sweet corn.

This borer has not been found in any of the above weeds except where they were growing near infested smartweed, and apparently it goes to them in fall as a more desirable place to hibernate than the smartweed stems. It has not been found in the stems of any weeds where such stems were hard and woody, although it may be abundant in the softer parts of the same plants. In some fields where the smartweed was very heavily infested, the borers were found fully as numerous in the stems of some other weeds, as is shown by the following comparative counts made in plants other than smartweed:

Corn	20
Amaranthus retroflexus	108
Lamb's-quarters	19
Ragweed	23
Smartweed	99
Barnyard grass	2

FIG. 5*a*
Larvae of the
Smartweed borer | European corn-borer

So far as can be learned from the observations this season, no real injury has been done by this native borer. Although as many as twenty

of the insects have been found in a single corn-stalk, and one in the stem of the ear of the corn, no injury to the corn had resulted.

Another closely related borer occurs in the stems of the Nelumbo or western water-lily or chinquapin ("yonkapin"). This species, so far as known, does not infest any other plant.

Other Insects likely to be mistaken for the European Corn-borer

In addition to the native borers already mentioned as closely related to the European corn-borer there are several others which might easily be mistaken for it by one not familiar with it.

The Corn Ear-worm.—The most common of the above class is the corn ear-worm, a grayish, brownish, or greenish caterpillar found boring in the ends of the ears of sweet and field corn. When fully grown this caterpillar is about one and a half to two inches long, and varies greatly in its color and markings, some specimens being dark green with very few markings on the back or sides, others a light gray with quite distinct stripes, and still others coming somewhere between these extremes. When placed under the microscope the skin of this caterpillar is seen to be covered with minute, dark, stubbed spines, which readily distinguish it from the European corn-borer, as the latter has no such spines. In addition to this character, the abdominal pseudopods of the ear-worm have an apical tranverse band of hooks, and not an almost complete circle as in the corn-borer. On becoming full-grown the ear-worm enters the ground and changes to a pupal or resting stage, in which it passes the winter, coming out early in spring as a yellowish or yellowish gray moth, with irregular dark spots distributed over the wings. The moth has a wing expanse of about one and a half inches, and flies mostly at night, feeding on the nectar of flowers. It is much more robust than the moth of the European corn-borer the thorax and abdomen being much stouter. The moths are very strong fliers, and, with a good wind behind them, may travel considerable distances, probably several miles. There are three generations of the ear-worm in each season, the moths of the first generation laying their eggs on green, succulent plants and weeds, on the stems or leaves of which the larvae feed. The second generation feed on leaves of various plants, especially on sweet corn. Moths of the third generation appear about the time that the late and medium-late corn is in the fresh silk stage, and deposit their eggs in large numbers on the silks of such corn. These moths vary greatly in abundance from year to year, being usually most abundant after one or two dry seasons. This is one of our most destructive corn insects, especially injurious to sweet corn. Some of the large corn-canning companies in this state have sometimes suffered losses of $30,000 to $40,000 in a single season, due to the ear-worm. In this state, corn is the principal crop injured by it, but

it also injures the fruit of the tomato, and in southern Illinois it is a serious pest of tobacco and cotton.

The Fall Army-worm.—Another insect very likely to be mistaken for the European corn-borer is what is commonly known as the fall army-worm. The larva of this insect has very much the same external appearance as the corn ear-worm, except that we never find any specimens of a solid green. It is often found feeding in the ends of ears of corn, although it usually has much the same feeding habits as the true army-worm. It can be distinguished from the corn ear worm by the fact that under the microscope the skin appears smooth with very minute black dots. Like the corn ear-worm, this insect belongs to the night-moth family (Noctuidae), and it has the claws of the abdominal pseudopods in a transverse band. It can not survive the winter in Illinois, but the moths migrate northward each year from the Southern States. It occurs here in really injurious numbers only about one year in five to seven.

The Common Stalk-borer.—Another native borer somewhat resembling the European corn-borer in its manner of feeding is what is generally known as the common stalk-borer. Our attention is usually first attracted to this insect early in spring, by noticing small clumps of dead grass around the margins of fields, along roadsides, and in similar situations. If we examine these carefully, we shall find a very small caterpillar working inside the stems in the center of the clump. These larvae are brown with five white stripes, one down the middle of the back and two on each side. The side-stripes are interrupted for a considerable space near the middle of the body, so that usually one third or more of the body is entirely brown except for the stripe on the back, giving the insect somewhat the appearance of having been crushed or bruised about the middle. As the worms grow they leave the grass and burrow the stems of various weeds and cultivated plants. They frequently migrate into fields of grain or corn, burrowing in the stems of these plants, causing the heads of the grains to whiten and the corn plant to become misshapen, and often preventing the formation of an ear. They become full-grown about the middle of July to the last of August, changing to the brown pupal or resting stage in the stems of their food plants, and emerging in August and September as dark, grayish brown moths with the outer third of the wing lighter and separated from the inner two-thirds by a whitish cross-line. The wing expanse is about one and a half inches. These moths belong to the same family as the two previously mentioned. They fly at night, and lay their eggs in fall about the stems of the various weeds and grasses in the same situations in which the young larvae are found feeding in spring.

There are several other species which resemble the European corn-borer in the larval or worm stage. One of these is a tineid, the larva of which occurs in the stems of Spanish needles and other weeds along

with the smartweed-borer. This species is shown in Figure 8. It may be at once distinguished from the other borers by the presence of three bristles of the infraspiracular spot on the prothorax (Fig. 26), by the

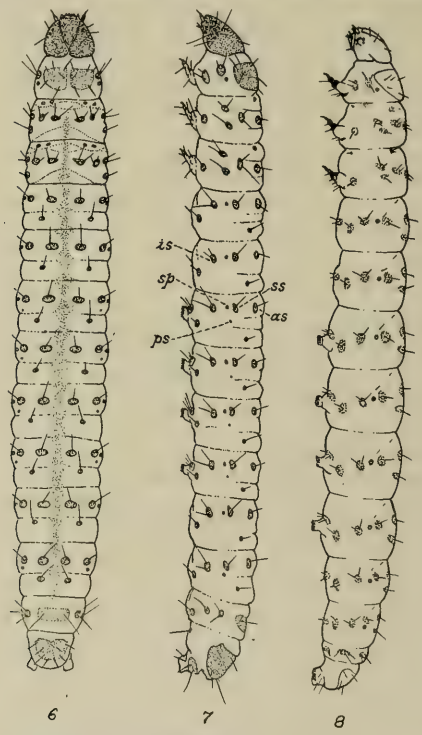


FIG. 6. Larva of *Pyrausta nubilalis*, dorsal view.
FIG. 7. Larva of *Pyrausta nubilalis*, lateral view: *is*, infraspiracular spot; *ss*, supraspiracular spot; *as*, anterior submedian spot; *sp*, spiracle; *ps*, postspiracular chitinized spot.
FIG. 8. Tineid larva from stems of Spanish needles (Bidens sp.).

number of bristles on the ninth abdominal segment (Fig. 27), and by the presence of a complete circle of claws, arranged in a single series, on the abdominal pseudopods.

Another species which bores in umbelliferous weeds and which also closely resembles the European corn-borer, is a small moth (*Depressaria heracleana*) of the family Tineidae which occurs in this country and in Europe. Like the tineid mentioned in the preceding paragraph it has three bristles on the infraspiracular spot on the prothorax (Fig. 23), but the bristling of the ninth abdominal segment is very different in the two species (cf. Fig. 27 and Fig. 24).

Briefly stated, there are many species the larvae of which superficially resemble the European corn-borer, but with the exception of the smartweed-borer none of them which are likely to be found in corn in Illinois present all of the group characters enumerated in the next paragraph as distinguishing the European corn-borer and its allies.

Doubtful specimens should always be sent to the Natural History Survey, Urbana, Ill., so that their identity can be established with certainty.

Distinguishing Characters of the Corn-borer Group

(Pyrausta nubilalis, P. penitalis, and *P. obumbratilis.)*

Larvae.—Body with conspicuous round black or brown setigerous spots, ten on each of the thoracic and abdominal segments except the prothorax and the apical two abdominal segments. These spots are always conspicuous on the dorsum, and in *penitalis* only are they almost obsolete below the level of the spiracles.

From species which have similar feeding habits the larvae may be distinguished by the following combination of characters: Prothorax with two bristles on infraspiracular and lateroventral spots (Fig. 13, 18), median abdominal pseudopods with an almost complete circle of small curved apical hooks which are arranged in three series at the broadest part of the circle (Fig. 21, 22), a small brown chitinized spot a short distance caudad of the spiracle on each of the segments which bear the pseudopods, supraspiracular spot on ninth segment with two bristles, the dorsum with a large transverse chitinized plate which bears two bristles, ocelli six in number, subequal in size, skin with minute chitinized dots at least on dorsum but wihout protuberances.

Pupae.—Pygofers present but not very pronounced, fore femora exposed, tarsi not exceeding apices of wing-cases, apical segment with a number of curved bristles resembling small hooks; abdomen with very few hairs, and without distinct protuberances other than some very minute paired teeth on each side of the median line on dorsum.

Adults.—The group belongs to the family Pyralidae, subfamily Pyraustinae, genus Pyrausta. The species are very similar in general appearance, being yellowish or brownish with the basal and submarginal lines brown as a general rule, but in the case of *nubilalis* and some specimens of *penitalis* there is a tendency to have the fore wings with a more

or less distinct broad central dark fascia between the dentate lines. In all three species the hind wings have distinct markings.

Not infrequently specimens of larvae, pupae, or adults are found under circumstances which suggest the possibility of their being the European corn-borer, and in order to decide whether or not they do belong to that species it is necessary to subject the specimens, at least the larvae or pupae, to a careful microscopic examination. The principal character by means of which the European species may be distinguished from its nearest allies is fortunately almost invariably perceptible by means of a hand lens with a magnification of ten diameters. The specific characters enumerated in this paper have been ascertained from an exhaustive examination of large series of specimens of the three species involved.

The European Corn-borer

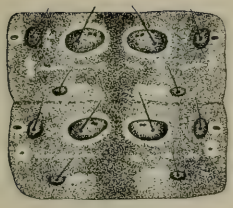
(*Pyrausta nubilalis* Hüb.)

Larva (Fig. 6, 7).—In the size and comparative distance between the anterior submedian dorsal spots on the abdomen this species approaches very closely to *penitalis,* but the minute chitinized points on the skin surface are continued much below the level of the spiracles and the infraspiracular and lateroventral spots are conspicuously blackish or brownish. Bristles of the prothorax and of the eighth and ninth abdominal segments as in Figures 13, 14, and 15.

From *obumbratilis* (Fig. 9, 5*a* left) this species may almost invariably be distinguished by the much more widely separated anterior submedian dorsal spots on the abdominal segments (Fig. 5*a* right, 10), these being separated by a much greater distance than the diameter of one spot, by the almost uniformly colored lateroventral spots (Fig. 16), the arrangement of the bristles laterocephalad of the abdominal pseudopods (Fig. 21); under a very high power lens, by the less compact nature of the chitinized points on the skin, their less close approximation to each other, and the less complete series of dots in the interspaces (Fig. 12); and, seen under a very high power, the arrangement of the hairs and the small puncture slightly above the level of the ocelli differ from the same in *obumbratilis* as shown in the composite Figure 25, left side of figure.

Plate XXIX.—Fig. 9. *Pyrausta obumbratilis,* second and third abdominal segments, from above. Fig. 10. *Pyrausta nubilalis,* the same. Fig. 11. *Pyrausta obumbratilis,* skin surface, highly magnified. Fig. 12. *Pyrausta nubilalis,* same. Fig. 13, 14, 15. *P. nubilalis,* prothorax, and 8th and 9th abdominal segments, from the side. Fig. 16. *P. nubilalis,* lateroventral spot. Fig. 17. *P. obumbratilis.* same. Fig. 18, 19, 20. *P. penitalis,* prothorax and 8th and 9th abdominal segments, from the side. Fig. 21. *P. nubilalis,* abdominal pseudopod. Fig. 22. *P. obumbatilis.* same. Fig. 23, 24. *Depressaria heracleana,* prothorax and 9th abdominal segment, from the side. Fig. 25. Composite head of Pyrausta: *nubilalis,* left side of figure; *obumbratilis,* right side. Fig. 26, 27. Tineid sp., prothorax and 9th abdominal segment of larva, from the side.

PLATE XXIX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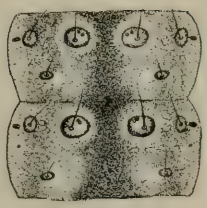
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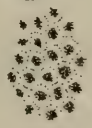
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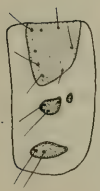
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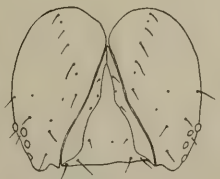
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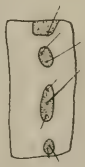
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PLATE XXX

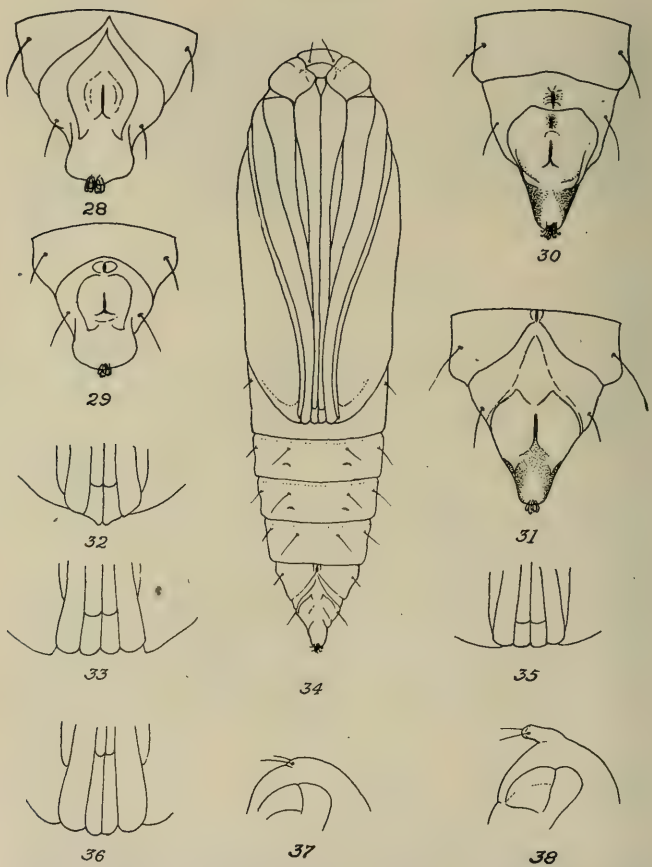


PLATE XXX.—Fig. 28. *Pyrausta penitalis*, apex of pupa of female. Fig. 29. *P. penitalis*, same of male. Fig. 30. *P. nubilalis*, apex of pupa of male. Fig. 31. *P. nubilalis*, same of female. Fig. 32. *P. penitalis*, apices of thoracic and cephalic appendages of pupa, male. Fig. 33. *P. penitalis*, the same of female. Fig. 34. *P. nubilalis*, pupa, male. Fig. 35. *P. nubilalis*, apices of thoracic and cephalic appendages, male. Fig. 36. *P. obumbratilis*, the same, female. Fig. 37. *P. nubilalis*, pupa, side view of cephalic extremity. Fig. 38. *P. obumbratilis*, the same.

Pupa (Fig. 34).—The pupa is readily distinguished from that of *obumbratilis* by the absence of the blunt protuberance on the head (Fig. 37, 38). In general it more closely resembles *penitalis,* but the dorsal abdominal segments have distad of the fine bristles two pairs of minute teeth on each side of the median line. These teeth are very much smaller in *penitalis* and *obumbratilis* than in *nubilalis.* The apical segment in both sexes of *nubilalis* is much narrower than in *penitalis,* as shown in Figures 30 and 31. In the comparative lengths of the maxillae and antennae there is but little difference between *nubilalis* (Fig. 35) and *penitalis,* but in *obumbratilis* the antennae and maxillae are considerably shorter than in the other two species.

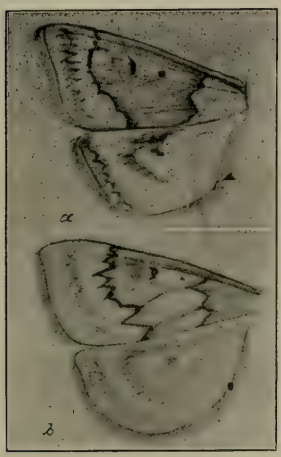


FIG. 39. Wings of the left side *(a)* of *Pyrausta nubilalis,* female, and *(b)* of *P. penitalis,* female.

Adult.—This species is the darkest of the group, the male in particular being very dark. We have figured the wings of the female (Fig. 39, *a*). In the male the central band of fore wings, the base proximad of the indented line, and the tip beyond the submarginal line are usually dark brown, leaving only two narrow notched yellow fasciae, one before and the other beyond the middle. The hind wings of the male are much darker than those of the female, the only yellow portion being a moderately broad band across middle.

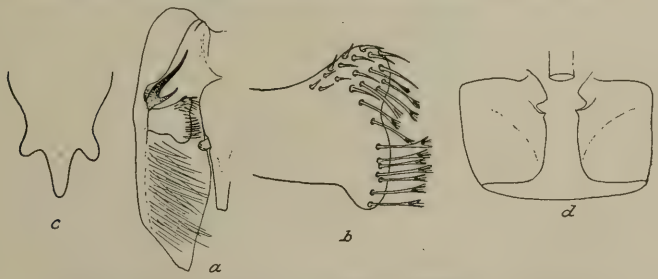


FIG. 40. European corn-borer *(Pyrausta nubilalis): a,* male hypopygium, one side; *b,* central process, more enlarged; and *c,* dorsal plate. Female penultimate abdominal segment, *d.*

The face is produced but little beyond anterior margin of eyes in profile, is convex, with an almost imperceptible carina at anterior margin, beyond which it is declivitous. The male hypopygium is as shown in Figure 40, the strong appendiculate thorn above middle of each clasper being very different from the two small thorns present in *obumbratilis*. The process at middle of each clasper (Fig. 40) is more like that of *obumbratilis* than that of *penitalis*. In the specimens before me the submarginal line in fore wings is less distinctly dentate posteriorly than in any of the other three species (Fig. 39, *a*).

The Nelumbo-borer
(*Pyrausta penitalis* Grote)

Larva.—The dark chitinized points on the skin, which form the color pattern on the dorsum and sides of the other two species are not continued below the level of the spiracles in *penitalis*, and the infraspiracular and lateroventral spots are not darker than the surrounding skin, though chitinized (Fig. 18, 19, 20). The anterior submedian dorsal spots on the abdomen are separated by much more than the width of one of the spots as is the case in *nubilalis*. The prothorax has the small chitinized points proximad of the dorsal plate much more evident than in either of the other species.

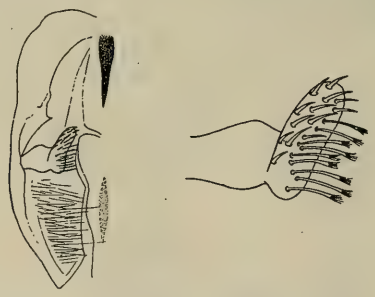


Fig. 41. Nelumbo-borer *(Pyrausta penitalis)*: male hypopygium, one side, and median process much more enlarged.

Pupa.—Distinguishable from *nubilalis* by the much broader apical segment in both sexes (Fig. 28, 29), and the smaller paired teeth beyond the bristles on the dorsal segments of the abdomen. Apices of thoracic and cephalic appendages as in Figures 32 and 33.

Adult—Larger than *obumbratilis*, usually averaging as large as *nubilalis*, 27–35 mm. in expanse of wings. Freshly emerged specimens are more reddish than any of the other species included in this paper. The

submarginal line is more pronouncedly dentate than in *nubilalis* (Fig. 39, *b*).

The face is much more distinctly produced than in *nubilalis*, the anterior margin being carinate and more or less distinctly arched in middle, sometimes almost pointed above. The male hypopygium differs from that of *nubilalis* in having no thorns above at middle of claspers and the process differently shaped (Fig. 41).

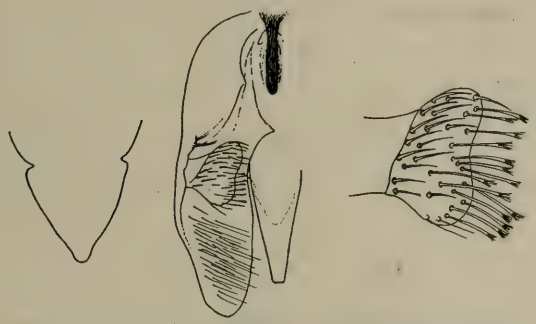


FIG. 42. Smartweed-borer *(Pyrausta obumbratilis)*: male hypopygium, one side; median process (right) much more enlarged; and (left) dorsal plate.

THE SMARTWEED-BORER

(*Pyrausta obumbratilis* Led.)

Larva.—More slender than either of the other two species and normally more conspicuously spotted, the spots larger and darker.

Differs from *nubilalis* in having the anterior submedian dorsal spots on abdomen separated by less than the diameter of one spot (Fig. 9), the ventrolateral spot with a conspicuous lunate black upper margin (Fig. 17), the bristles cephalolaterad of the pseudopods differently arranged (Fig. 22), and the small chitinized dots on the skin less evidently composed of minute contiguous points, the dots being separated on the greater portion of the body by less space than the diameter of a dot, the series of minute points in the intervening spaces being more complete (Fig. 11); and the bristles near ocelli (Fig. 25, right side) being differently arranged.

Pupa.—Distinguishable from either of the other two species by the prominent protuberance on the head as shown in Figure 38. The apical abdominal segment is very similar to that of *nubilalis*, but the small

paired teeth on the dorsum of the abdomen are much smaller in this species. Apices of thoracic and cephalic appendages as in Figure 36.

Adult.— Much paler than *nubilalis*. The submarginal line is much more deeply indented, being similar to that of *penitalis*. The male hypopygium has two small thorns instead of the long stout appendiculate thorn which is present in *nubilalis* (Fig. 42), and the process at middle of the clasper is slightly different in shape and more numerously bristled (Fig.. 42). The face is not so much elevated at anterior margin as in *penitalis*, but has a slight carina beyond which it is declivitous. Usually the specimens average smaller than those of the other two species.

Pyrausta caffreii, sp. n.

Adult.—This species closely resemble *obumbratilis*, the color and markings being very similar. The general color of the fore wings of the two females before me is a clear straw-yellow, with the markings linear and pale brown. The male which I have is badly deformed and the wings, owing to their being only partially developed, are darker than in the females, having many brownish scales apically. It is not possible to

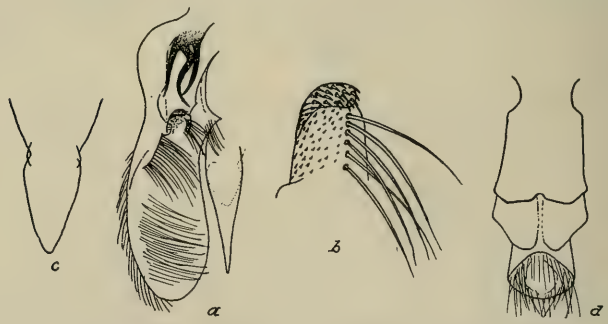


FIG. 43. *Pyrausta caffreii*: *a*, male hypopygium, one side; *b*, central process, more enlarged; and *c*, dorsal plate. Female genital segments, *d*.

describe the wing markings from the male but those of the female are almost identical with those of *obumbratilis*, the submarginal line being deeply indented posteriorly. The male hypopygium is strikingly different from that of any of the other three species as shown in Figure 43. The principal distinction lies in the presence of three long spines arising from a common base at base of each clasper. In addition to this there are striking differences in the shape of the process at middle of the clasper and in its surroundings. The face in both sexes is almost conically produced and

very different from that of any of the other species (Fig. 44). Female apical segments as in Figure 43.

We consider it proper to assign a name to this very well-defined species though it may eventually prove to have been already described. A careful examination of the hypopygia of all the species in the genus is essential to a clearing up of the synonymy.

Type, male, Bloomington, Ill., September 30, 1919, taken in a field of sweet corn which was destroyed by larvae of the fall army-worm (J. R. Malloch). Allotype and one female paratype without locality labels.

Named in honor of Mr. D. J. Caffrey, who kindly supplied much of the material for the study of *nubilalis*.

The immature stages and food plant of this species are unknown to us at this time.

For the identification of *obumbratilis* we are indebted to Dr. W. T. M. Forbes who, on a visit here some months ago, thus identified several specimens in our collection, some of which had been reared from cornstalks in which the larvae had evidently passed the winter. This species was not included in the Twenty-third Report of the State Entomologist—"A Monograph of Insects Injurious to Indian Corn"—as its habits were not known here until a year after that report appeared, the first Illinois specimen being reared in 1906.

After this paper had been prepared for the press and before it was sent to the printer there appeared in the *Journal of Agricultural Research* a paper by Carl Heinrich on the European corn-borer in which the name *Pyrausta ainslici* is given to the species here designated as *obumbratilis*. We have examined the series of *obumbratilis* in the collection of Dr. Wm. Barnes, which contains some specimens reared by Kearfott from Typha (cattail-flag), and after comparing the genitalia of one of the males of the reared series with some of those in our collection we are convinced that they are identical with *ainslici* Heinrich. The basal spine, which is not figured by Heinrich, is easily detached from the genitalia in dissection, and is really present in the species he figures but evidently was lost in dissecting the specimen.

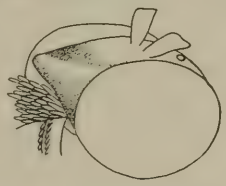


FIG. 44. *Pyrausta caffreii*, head of male from side; palpi, antennae, and proboscis incomplete.

ERRATUM

Fig. 5a, page 293, was reversed in printing; the two items of the legend should change places.

ARTICLE XI.—*A Study of the Malarial Mosquitoes of Southern Illinois. I. Operations of 1918 and 1919.* BY STEWART C. CHANDLER.

INTRODUCTION

The Relation of Mosquitoes to Malaria.—The part which mosquitoes play in the transmission of malaria was established years ago, but we often find people who never heard of the relation between the two. It is therefore important to make clear, at the beginning of this report on mosquitoes, the facts in the case. Malaria was at first thought to be carried to men by damp night air. "Mal-aria," bad air, was the name given to the disease for that reason. It was later clearly established that mosquitoes breeding in the swamps and other damp places and biting at dusk are the sole carriers of the disease. A mosquito, upon biting a malaria patient in whom the disease parasites have developed for about ten days, sucks up the parasites into her mouth. Only the female mosquito bites and is capable of transmitting the disease. The germs now develop for a period of eight to ten days. In this time they break through the lining of the stomach wall and get into the salivary glands, from which they are readily transferred to man by the bite of the mosquito. Not all kinds of mosquitoes are malaria carriers. Only three species in this country (all belonging to the genus Anopheles) are implicated. There are in all twenty-four species of mosquitoes regional in Illinois.

Malaria in Southern Illinois.—Illinois is not usually regarded as a state in which malaria is common; and the northern two-thirds would not be so classed. Southern Illinois, however, has a reputation not so enviable. I have found it impossible to secure correct statistics on the extent of malarial disease. Most physicians whom I have consulted do not keep records of malaria such that they can say definitely how many cases they have treated in a year's time. They report irregularly or not at all on this disease to the State Board of Health. Estimates, of course, can be secured from them, and I have always found physicians whom I have consulted very willing to make as careful estimates as possible. Taking as examples the two towns in which I have done most of my survey work, Carbondale and Murphysboro, I found that the estimates gave Carbondale from a hundred and fifty to two hundred cases of malaria in an average year, and Murphysboro from two hundred to four hundred cases. As these are towns of six and eight thousand population, respectively, we find that from two to five out of every hundred men, women, and children are attacked by malaria each year. There are many other points in southern Illinois, especially along the Mississippi, Wabash, and Ohio rivers, which are greater malaria centers than the towns men-

tioned, but estimates from these places are so widely divergent that I am not presenting them at this point. The State Board of Health estimated, for the period of 1909 to 1914, (Vol. II, No. 6 of Illinois Health News,) that in ten of our southern Illinois counties at least 8 per cent. of the population was ill from malaria each year. They put the number of cases for the state at nineteen thousand per annum, and the number of deaths from malaria at ninety-five per annum. Most of the physicians whom I consulted said that deaths from this cause are becoming increasingly rare, because of increased drainage in some sections and the fact that most people now understand the value of quinine and more of them than formerly screen their houses. The State Board of Health, in an endeavor to assign a money loss attributable to the disease in the state, estimates that the average loss to the individual patient due to medical attendance, cost of remedies, and diminished earning power is $160.00, amounting to over three million dollars for the nineteen thousand cases. There is another form of loss which is not always taken into account in speaking of a disease, namely, loss of vitality. Very often the patient is able to work, but only with a greatly decreased vigor, resulting in a loss, if not to the worker, at least to his employer. This reduction of efficiency is recognized in southern Illinois especially by big corporations, like the railroads, which have large numbers of employees.

Object of the Survey.—It was in view of facts of this nature that the Southern Illinois Medical Society passed a resolution in the fall of 1917 requesting the State Natural History Survey to make a mosquito survey of southern Illinois in order to locate the breeding-places of malarial mosquitoes, with a view to eventual efforts for the control of the insects and the prevention of malarial disease. This work has been carried on during the seasons of 1918 and 1919 as continuously as was consistent with the press of other duties. It was thought best to limit the work to one or two towns chosen as typical rather than to attempt to cover a large territory more superficially.

It has been the main object of the survey to find the kinds of places in which malarial mosquitoes breed in southern Illinois and to learn which kinds are clearly preferred and how continuously and to what extent the various species abound through the year. From these data, together with those obtained from physicians, certain conclusions have been drawn in respect to the relation between the amount of malarial disease on the one hand and the number of malarial mosquitoes, the proximity of their breeding-areas, and the distances to which they are capable of flying, on the other.

Life History.—A brief account of the life history of the mosquitoes will aid those not familiar with their habits to appreciate the importance of a knowledge of their breeding-places.

In spring adult mosquitoes appear as the weather warms up, some as early as March in southern Illinois. The eggs are laid on some body of water, temporary or permanent, large or small. If the female finds

no water, she may die without reproducing, a fact to be borne in mind when control measures are considered. At least a day is necessary to bring the eggs to hatching—considerably more in late fall or early spring. The larval mosquitoes, commonly known as wigglers, are seen swimming in ponds, creeks, and other breeding-places, or floating at the surface, which they must visit at frequent intervals for a supply of air. They feed upon minute aquatic plants and animals. The larval period varies from one to three weeks, according to season and temperature. In the pupal stage, which is passed in the water and lasts from one to five or more days, the head and thorax are much larger than in the larva. The length of the entire life cycle depends on the time of year and the species. It is from ten to twenty-five days, being generally a little longer in the genus Anopheles, to which the malaria-carrying mosquitoes belong, than in other genera. One authority* (Howard Dyar, and Knab) gives twelve to twenty-four days as the total length in May and June for the Anopheles in Washington, D. C. In planning the treatment of breeding-places, we must remember that the entire life cycle of the mosquito may be passed in ten days, and that successive generations will be produced as long as warm weather continues and breeding-places are available. The stage of hibernation varies with the species, but it is fairly well established that of Anopheles only the females survive the winter. I have found these during the winter at Carbondale in cellars, culverts, and other sheltered places.

Survey Work at Carbondale

Frequency of Malarial Disease.—Four physicians who had practiced for many years in Carbondale, gave the following estimates of the number of cases of malaria treated in the town in an average year: Dr. J. W. Barrow, 200; Dr. Roscoe Lewis, several hundred; Dr. W. A. Brandon, 150; and Dr. H. C. Mitchell, 150. As the population of the town is about six thousand, it would appear that at least two or three out of every hundred are treated for malaria each year.

Mapping the Territory.—A map of Carbondale township—not reproduced in this report—was traced, on which I indicated most of the possible breeding-places of mosquitoes. It was my first intention to make examinations in the country as well as the town, and I designated on this map about twenty-five tributaries and feeders of Crab Orchard Creek, a stream about two miles east of Carbondale. The doctors whom I interviewed had told me of the continued occurrence of malaria among the farmers along this creek and I later found malarial mosquitoes breeding in these tributaries. Lack of time compelled me, however, to confine my attention to the town and immediate surroundings. The breeding-places were numbered in my notes and on the map for ease in recording findings. Larger maps of Carbondale and vicinity were

* "The Mosquitoes of North and Central America."

obtained from the Illinois Central Railway division office through the courtesy of Supt. W. Atwill, and from Mr. C. E. Cox, a former civil engineer. By means of these larger-scale maps I was able to indicate practically every possible breeding-place of mosquitoes which would be likely to affect the people of Carbondale. Although winds may carry mosquitoes for a distance of several miles (as will later be shown in the case of Anna and Jonesboro) it is usually believed that mosquitoes do not fly over half a mile from their breeding-places. Most of the places examined are within half a mile of the edges of town. (Maps, pp. 312, 313.)

Examinations and Collections.—Collections of larvae and pupae were made once, and sometimes twice, a month during the breeding seasons of 1918 and 1919 (with the exception of September, 1919) and were bred to the adult for identification. The wigglers were scooped up with a small strainer with a handle and a screen of about twenty meshes to the inch. They were removed with a small soft brush, such as is used in water-color work, and put temporarily into tin pill-boxes together with a little of the same water in which they were found. The contents of the pill-boxes were later emptied into glass jars in the insectary and more water with aquatic vegetation and some of the mud from the bottom was poured into the jars to furnish food and natural conditions. I usually secured this water from some one or two breeding-places which seemed to produce mosquitoes abundantly, taking care to exclude mosquito larvae and any animals which might be predaceous upon the mosquitoes. Notes were made as to the presence and abundance of the malarial and non-malarial mosquitoes in each breeding-place examined, and the species were later determined by Dr. C. P. Alexander and Mr. J. R. Malloch, of the Natural History Survey.

The Anopheline and Culicine larvae (carriers and non-carriers of malaria) are readily distinguished by the positions which they take while resting at the surface of the water, the Anophelines lying parallel to the surface while the Culicine larvae hang down at an angle of about forty-five degrees, with only their long breathing tubes touching the surface. The pupae are more difficult to distinguish and will not be discussed. The adults of our Anopheles are easily distinguished from Culex and other genera by the spots on the wings, the Culicine wing being clear. The palpi of the female are longer in Anopheles than in Culex. The body of the Anopheline adult forms an angle with the surface upon which it rests, while that of the Culicine is parallel to the surface.

BREEDING-PLACES

Mosquito breeding-places at Carbondale are typical of those in many other towns. In the following description I am grouping them in classes which will be readily recognized by residents of other places. The breeding-places were numbered, as shown on the maps (pp. 312-313), to facilitate the making of records. Plates XXXI—XXXV illustrate a few of the situations.

Class I, Swamps.—The swamps studied are of a type common in the southern end of the state. Most of them are grown up to cattail, the density of which will be realized by reference to Fig. 1 and 2. The water generally contains a great deal of decayed organic matter. Around the edges usually, and in the main channels (if there are any), the water is clearer. At Carbondale the railroad shops, round-house, and yards are in a series of these swamps (Nos. 54–57, 59, 61). The physicians in town have all spoken to me of the large number of cases of malaria among the railroad men, and I do not doubt that these swamps are partly responsible.

Class II, Marshes.—A marsh, as the term is here used, is not as deep as a swamp, does not contain so much organic matter, and contains a considerable growth of grass besides some cattails. In Carbondale such a place (No. 71) is found opposite the old cemetery near the negro school. This place (Fig. 3) produced many malarial mosquitoes.

Class III, Ponds.—The ponds at Carbondale are small bodies of water artificially formed. No. 58* in the A. & L. Tie Company's yards and their two "creosote lakes" (Nos. 66 and 67), No. 52 on Chestnut street, No. 45 east of Freeman street, and the pond on the campus of the State Normal School (No. 179) are examples. The growth in these ponds varies from none at all, as in the Tie Plant property, to that of a swamp.

Class IV, Roadside Ditches.—Especially along built roads there are often left ditches which contain water and are grown up to grass or cattail. Numbers 62 and 63*, near the Illinois Central yard office, are types. Many other ditches show no growth at all and, as will afterwards be shown, yield comparatively small numbers of mosquitoes.

Class V, Creeks and Streams.—Crab Orchard Creek and its tributaries, Pyles Fork and a creek (No. 53) running into the swamps north of town, are those which I watched most closely.

Class VI, Open Drains through Towns (Fig. 4, 5, 6, 7).—These drains may originally have been natural streams, but in the case of the two watched at Carbondale (Nos. 47 and 48), their courses have been somewhat altered.

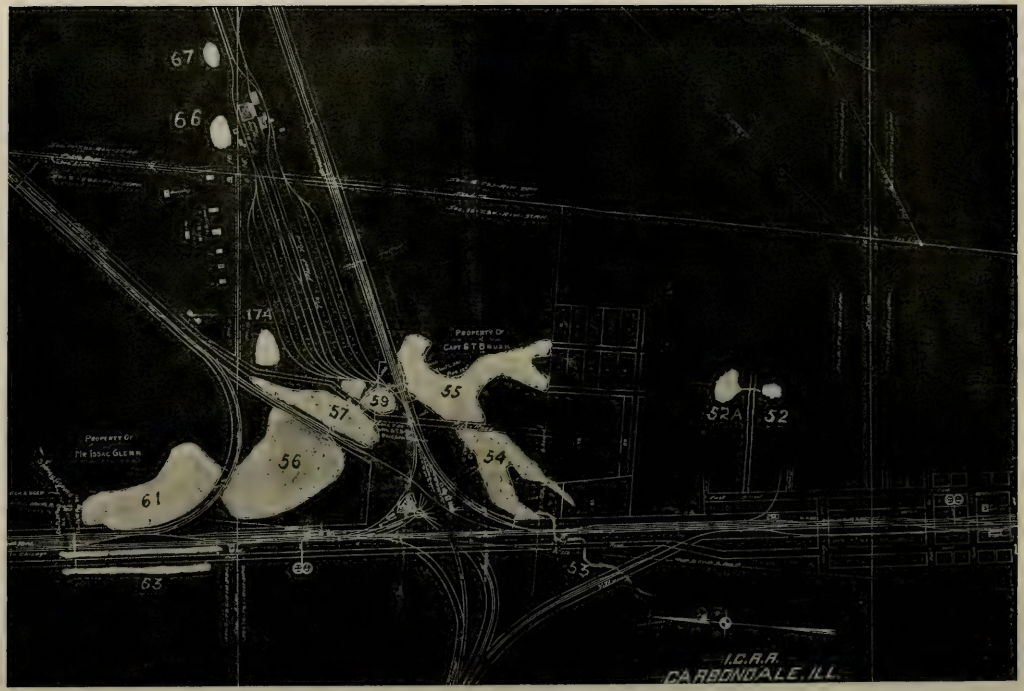
Class VII, Lakes.—Thompson's Lake (No. 51, Table A) at the south edge of town is leased by the Country Club and is consequently much visited by many of the residents. It is also important because of its proximity to town.

Mosquito-producing Factors of Various Types.—While all of these kinds of breeding-places yielded Anopheles, it soon became apparent that some were much more productive than others.

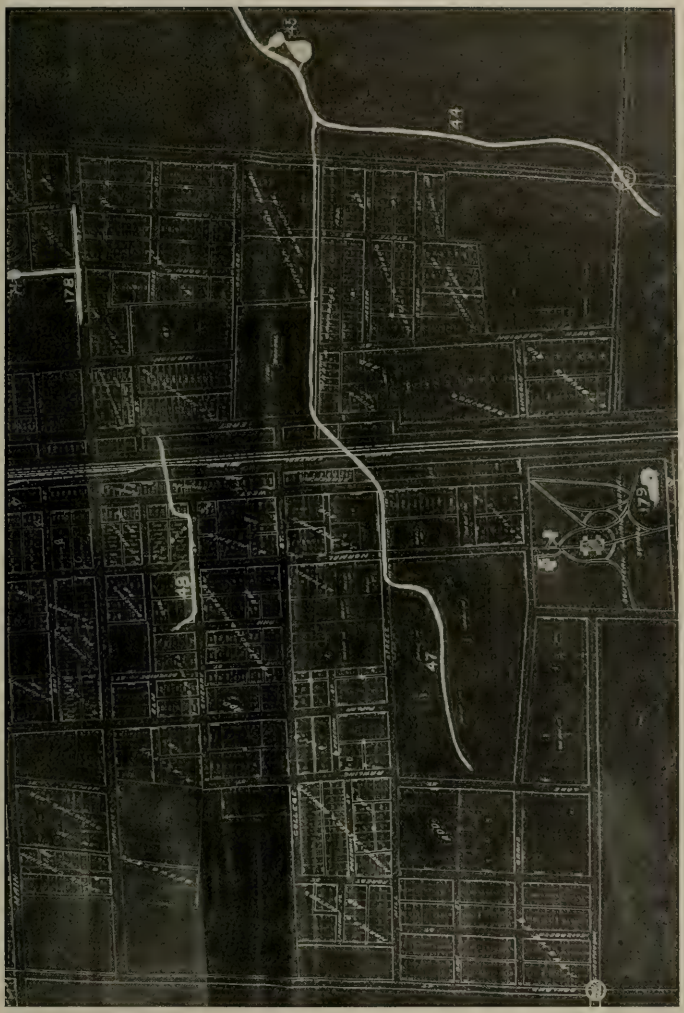
The cattail swamps might be supposed, from their large area, to breed more malarial mosquitoes than any other waters, and they are no doubt important, although they present certain features which seem to decrease the output. I have found some of them yielding these mosquitoes in

* No. missing on map.

[Continued on p. 317.]



North half of Carbondale. (North at left side)



South half of Carbondale. (North at top)

A

PREVALENCE OF MOSQUITO LARVAE IN CARBONDALE BREEDING PLACES

Type of breeding place	B. P. No.	Season of 1918				Season of 1919			
		Date	Anopheline	Culicine	Remarks	Date	Anopheline	Culicine	Remarks
		April				April			
Cattail swamps	54	18	None	Few		2	None	None	
	54	.....	.....	.....		28	None	None	
	55	19	None	Few		24	None	None	
	56	18	None	Few		24	None	None	
	57	18	None	Few		24	None	None	
	59	.....	.....	.....	No examination	24	None	None	
	60	.....	.....	.....	No examination	.....	.....	.....	No examination
	61	18	None	Many		24	None	None	
Marsh	71	.....	.....	.....	No examination	30	Fair numbers	Few	
Pond	179	.....	.....	.....	No examination	30	None	None	
Roadside ditch	62	.....	.....	.....	No examination	24	None	None	
	63	18	None	Many		24	None	Few	
Stream	53	.....	.....	.....	No examination	3	None	None	
Open drains	47	.....	.....	.....	No examination	24	None	None	
	48	.....	.....	.....	No examination	24	None	None	
Lakes	51	.....	.....	.....	No examination	2	None	Many	
		May				May			
Cattail swamps	54	14	None	Few		28	None	Fair numbers	
	55	.....	.....	.....	No examination	28	Fair numbers	Few	
	56	15	None	Few		27	None	Many	
	57	14	Very few	Very few	1 adult Anopheline	28	Few	Few	
	59	.....	.....	.....	No examination	28	None	Few	
	60	.....	.....	.....	No examination	28	Few	Fair numbers	
	61	15	None	Few		27	Many	Few	
Marsh	71	16	Fair numbers	Fair numbers		15	Many	Fair numbers	
Pond	179	.....	.....	.....	No examination	27	Few	None	
Roadside ditches	62	.....	.....	.....	No examination	27	Fair numbers	Fair numbers	
	63	14	Few	Few		27	Few	Few	
Streams	53	.....	.....	.....	No examination	27	Fair numbers	Fair numbers	
Open drains	47	17	None	None	Rain, strong current	27	Fair numbers	Few	
	48	16	None	Few	Adults	27	None	Many	
Lakes	51	17	None	Fair numbers		28	Fair numbers	Fair numbers	
		June				June			
Cattail swamps	54	29	Fair numbers	No record		.....	.....	.....	No examination
	55	24	Few	Few		17	Many	Very few	
	56	24	Many	?		17	Fair numbers	None	
	57	3	Fair numbers	Fair numbers		17	Many	None	

	59	24	.....	.....	Dried up	17	Many.....	Very few	
	60	24	.....	.....	Dried up	17	Many.....	Very few	
	61	24	Few.....	?		.....	.....	.....	No examination
Marsh.....	71	24	.....	.....	Dried up	18	Many.....	Very few	
Ponds.....	179	10	Fair numbers	Few.....		.....	.....	.....	No examination
Roadside ditches....	62	25	.....	.....	Dried up	.....	.....	.....	No examination
	63	3	Fair numbers	Fair numbers		.....	.....	.....	No examination
	63	20	Fair numbers	?					
Streams.....	53	3	Many.....	Many.....		.....	.....	.....	No examination
Open drains.....	47	3	Many.....	Very few.....		18	Very many...	None	
	48	4	Few.....	Very many...		18	Many.....	Very few	
Lakes.....	51	4	Few.....	?		.....	.....	.....	No examination
		July				July			
Cattail swamps.....	54	19	.....	.....	Dry	.....	.....	.....	No examination
	55	19	None.....	None.....	Dry, except in main channel	4	Many.....	None	
	56	18	None.....	None.....	Dry, except in main channel		.....	.....	No examination
	57	19	None.....	None.....	Dry except in main channel		.....	.....	No examination
	59	.....	.....	.....	No examination		.....	.....	No examination
	60	.....	.....	.....	No examination		.....	.....	No examination
	61	18	None.....	None.....	Water in main channel only		.....	.....	No examination
Marsh.....	71	.....	.....	.....	No examination	4	.....	.....	Dry
Pond.....	179	18	Fair numbers	Fair numbers			.....	.....	No examination
Roadside ditches....	62	.....	.....	.....	No examination				
	63	18	None.....	None.....	Nearly dry	4	Many.....	None	
Streams.....	53	13	Fair numbers	?			.....	.....	No examination
Open drains.....	47	17	Many.....	Many.....	Nearly dry	4	Many.....	None	
	48	16	None.....	Very many...		.....	Many.....	None	
Lakes.....	51	20	.....	.....	Lake lowered 8 feet	.....	.....	.....	No examination
		Aug.				Aug.			
Cattail swamps.....	54	15	.....	.....	Dry	2	Very few.....	None	
	55	15	None.....	None.....	Nearly dry	2	Fair numbers	Few	
	56	16	Few.....	None.....		2	None.....	None	
	57	15	Few.....	Few.....	Water low	2	None.....	None	
	59	.....	.....	.....	No examination	2	Few.....	None	
	60	.....	.....	.....	No examination	2	.....	.....	Dry
	61	15	Fair numbers	Fair numbers		2	None	None	
Marsh.....	71	16	.....	.....	Dry	2	None.....	None.....	Dry
Pond.....	179	14	Fair numbers	?		2	Few.....	Very few	
Roadside ditches....	62	16	Many.....	Fair.....	Waste water draining in	2	Very few	None	
	63	16	None.....	Very many...		2	Fair numbers	Few	
Streams.....	53	16	Fair numbers	?			.....	.....	No examination
Open drains.....	47	12	Few.....	Fair numbers		2	Fair numbers	None	
	48	12	Very few.....	Very few.....	Almost dry	2	.....	.....	Dry
Lakes.....	51	.....	.....	.....	No examination	2	Fair numbers	Fair numbers	

PREVALENCE OF MOSQUITO LARVAE IN CARBONDALE BREEDING PLACES—Concluded

Type of Breeding Places	B. P. No.	Season of 1918				Season of 1919			
		Date	Anopheline	Culicine	Remarks	Date	Anopheline	Culicine	Remarks
		Sept.							
Cattail swamps	54	3	Many	Many	(Rain on Sept. 2)		No September examinations, 1919		
	55	3	Many	Few					
	56	5	Fair numbers	Fair numbers					
	57	5	Few	Fair numbers					
	59	3	None	Fair numbers	Water low				
	60	3	None	Many					
	61	5	Few	Many					
Marsh	71	3	None	Many					
Pond	179	5	Fair numbers	Few					
Roadside ditches	62	4	Many	?					
	63	4	Fair numbers	Many					
Stream	53	4	Fair numbers	?					
Open drains	47	6	Fair numbers	?					
	48	6	None	Few	Nearly dry				
Lakes	51	.....	.....	.....	No examination				
		Oct.				Oct.			
Cattail swamps	54	17	Few	Fair numbers		24	None	None	
	55	17	Few	?		24	Fair numbers	None	
	56	17	None	None		24	None	Many	
	57	17	None	None		24	Fair numbers	None	
	59	17	None	Fair numbers		24	Very few	None	
	60	.....	.....	.....	No examination	.....	.....	.....	No examination
	61	17	None	Fair numbers		24	None	None	
Marsh	71	17	.....	.....	Dry	24	Very few	Very few	
Pond	179	18	None	None		24	Few	Few	
Roadside ditches	62	17	Fair numbers	?		24	None	Few	
	63	17	Many	?		24	None	Few	
Streams	53	17	Fair numbers	?		24	Few	Few	
Open drains	47	17	Fair numbers	Many		24	Fair numbers	Fair numbers	
	48	17	None	Very many					
						24	None	None	
Lakes	51	.....	.....	.....	No examination	24	Few	None	
		Nov.				Nov.			
Cattail swamps	55	.....	.....	.....	No examination	15	None	None	
	56	.....	.....	.....	No examination	15	None	None	
	57	.....	.....	.....	No examination	15	None	None	
Pond	179	18	None	None		.....	.....	.....	No examination
Stream	53	18	None	None		.....	.....	.....	No examination
	47	18	Many	Fair numbers		.....	.....	.....	No examination
Open drains	48	18	None	None		.....	.....	.....	No examination

every month of the season, but not in numbers corresponding to their area. The large amount of organic matter which they contain seems to be detrimental to Anopheles larvae. At one time during a summer drouth the common duckweed (*Lemna minor*) completely covered the surface of a part of the swamp where cattails were absent, and I could find no mosquito larvae around the edges of this area.

The marshes (Class II) seem to produce more Anopheles than the swamps, probably because of a more favorable vegetation, as already noted.

Ponds (Class III) are dangerous if they contain sufficient vegetation to give shelter and protection to mosquito larvae. Grass, reeds, rushes, and cattails favor their escape from small fishes and predaceous insects. I was never able to find any mosquitoes breeding in Pond No. 58, in the Tie Plant yard, or in the "creosote lakes," the latter probably because of the cresote waste emptied into them. No breeding was found in No. 52 and very little in No. 45. The three Tie Plant ponds and No. 52 have no vegetation along the edges to furnish protection. No. 45 showed a growth of water-lilies which did furnish some protection, although not as effective as grass. The pond on the Normal campus (No. 179; Fig. 8 and 9) has a good deal of plant growth along the edges, and I found some Anopheles breeding there practically every time I looked for them. As some of this vegetation was cut down in the fall of 1918, it was not quite so abundant in 1919 as the year before, and Anopheles were also less abundant. Several physicians have spoken to me of the number of cases of malaria in the Normal dormitory, and I found Anopheles breeding within twenty feet of it (Fig. 8).

Roadside ditches (Class IV) generally contain less water than the other types, but they are likely to be mosquito breeders unless they dry up. Some of them, however, have no vegetation whatever and usually contain few or no wigglers. Numbers 62 and 63, by the Illinois Central yard office, lined with overhanging grass and filled with other vegetation, hold their water well through the season and furnish quite ideal conditions for Anopheles.

In creeks and streams (Class V) mosquito breeding is limited not only by vegetation and water supply, but also by strength of current and purity of water. In the main stream of Crab Orchard and Sycamore creeks and of Pyles Fork I found very little or no breeding except when, as in the case of Pyles Fork, dry weather reduced the stream to a series of pools. In the backwaters and in small tributaries with little current, Anopheles were often quite abundant. Small streams with little current, such as No. 53, running into the swamps, especially those with grassy banks,* may be prolific breeders. When waste water of any kind pollutes the stream it is likely to reduce mosquito production.

Practically the same may be said of Class VI (open drains) as of creeks and streams. They are, perhaps, more likely to become polluted

* See Fig. 12—a stream at Murphysboro.

by garbage or through sewer leaks, in which case I have noticed that the production of malarial mosquitoes is much more reduced than that of the non-malarial species. Where drains are left with weedy edges, as in Carbondale, they are a serious menace to the health of the town. Figures 4 to 6 show the ideal breeding conditions which these drains afford, and records of physicians show frequent cases of malaria in houses situated close to them. Fig. 6 shows the proximity of one ditch to a city school building.

The Thompson's Lake (Fig. 10) type of breeding-place is dangerous, providing there is sufficient protective growth along the edge to mask wave action, since this seems to be detrimental to the development of mosquito larvae. I am inclined to think, however, from the past season's experience, that Anopheles larvae prefer shallower water than is found even along edges of this lake, and that consequently it is not as important as some other breeding-places before mentioned. However, I found at least a few Anopheles upon practically every visit, and as there is a long shore-line the lake must have some effect on the amount of malaria.

Prevalence of Mosquitoes and Abundance of Malaria.—In the following table I am showing the presence and abundance of the mosquito larvae in the breeding-places which I was able to watch fairly continuously throughout the year. The six terms used to indicate the numbers of Anopheles—none, very few, few, moderate numbers, many, and very many—are given grades of 0, 1, 2, 3, 4, and 5, respectively, and the data for each month are figured separately, the records for the two years being combined. This table shows for each month the number of visits at which each of the six grades of abundance was found, the average abundance per visit for each month, and, in the lowest line of the table, the percentages of abundance, taking the highest grade (very many) as the base of the computation. In April, for example, the average abundance of larvae of malarial mosquitoes was 2.7 per cent. of "very many;" in May this average was 30.8 per cent.; in June, 67; and so on.

It was found impossible to obtain accurate figures on the prevalence of malaria in Carbondale, but from the medical record of the Illinois Central Railroad employees in town, kept by Dr. H. C. Mitchell, division surgeon, it is evident that the increase and decrease of the number of cases of malaria are closely correlated with the abundance and scarcity of the Anopheles mosquitoes.

Species.—The accompanying table (C) contains a list of the species of mosquitoes which were either taken as adults, or bred to the adult stage from larvae and pupae, during the last two seasons. It also shows the types of breeding-places in which they were found and the months in which the collections were made. The numbers used are those of the foregoing description of types, viz.: Class I, cattail swamps; Class II, marsh; Class III, ponds; Class IV, roadside ditches; Class V, streams; Class VI, open drains; Class VII, lakes.

B

ABUNDANCE OF MALARIAL MOSQUITOES IN DIFFERENT MONTHS AND DIFFERENT BREEDING PLACES, CARBONDALE, 1918 AND 1919.

Grades of abundance	April		May		June		July		August		September		October		November	
	No. of breeding places	Products	No. of breeding places	Products	No. of breeding places	Products	No. of breeding places	Products	No. of breeding places	Products	No. of breeding places	Products	No. of breeding places	Products	No. of breeding places	Products
None.....0	21	0	10	0	0	0	6	0	5	0	4	0	12	0	6	0
Very few.....1	0	0	1	1	0	0	0	0	3	3	0	0	2	2	0	0
Few.....2	0	0	5	10	4	8	1	2	5	10	2	4	5	10	0	0
Moderate numbers.3	1	3	6	18	6	18	2	6	7	21	5	15	6	18	0	0
Many.....4	0	0	2	8	9	36	4	16	1	4	3	12	1	4	1	4
Very many.....5	0	0	0	0	1	5	0	0	0	0	0	0	0	0	0	0
Totals of grades.	.....	3	.....	37	.....	67	.....	24	.....	38	.....	31	.....	34	.....	4
Totals of breeding places.....	22	.....	24	.....	20	.....	13	.....	21	.....	14	.....	26	.....	7	.....
Average abundance per breeding place	0.137		1.54		3.35		1.85		1.81		2.22		1.31		0.57	
Percentages of abundance,.....	2.7		30.8		67.		37.		36.2		44.3		26.2		11.2	

C

SPECIES OF MOSQUITOES TAKEN AS ADULT OR BRED FROM IMMATURE STAGES AT CARBONDALE AND MURPHYSBORO, 1918 AND 1919.

Species	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Uranotaenia sapphirina (O. S.) Lynch											1918
Arribalzaga.						7					1919
Anopheles guttulatus Harris				1, 6, 7			4	3			1918
			house, 6	7	1	1, 4					1919
Anopheles punctipennis (Say) Say			5	2, 3, 4, 5, 6, 7		5, 6	6	1, 4, 5			1918
		house	1, 2, 4, 5, 6, 7	1, 3, 5, 6, 7	6	1		1, 2 3			
		7						5, 6			1919
Culiseta inornata (Williston) Dyar			4, 5, 6	6							1918
			2								1919
Culex saxatilis Grossbeck				6						6	1918
			1, 2, 4	1				5			1919
Culex territans, Walker										6	1918
			6								1919
Culex pipiens Linn											1918
				5	6	5					1919
Culex salinarius Coquillett			1, 3	1, 6		6	6	1			1918
								1, 6			1919
Culex species (close to *jamaicensis* Theobald, which it is in sense of Felt but not of H. D. & K.)			3, 5								1918
Psorophora ciliata (Fabricius) Robineau-Desvoidy			7								1918
											1919
Psorophora sayi D. & K			4, 7								1918
											1919
Aëdes canadensis (Theob.) D. & K			1	2							1918
			5	1							1919
Aëdes sylvestris (Theob.) D. & K			1, 3, 4, 6	1, 2, 7				1, 4			1918
		7	5, 6, 7								1919
Aëdes sp. [near *taeniorhynchus* (Wiedemann) Busck]	1 adult near house Mar. 18										1918

Explanation of above table:—Under the columns for the months of the year the figures given (1 to 7) refer to the seven classes of breeding-places already described in the foregoing pages. The word "house" is self-explanatory, simply meaning taken in a house.

RELATIVE ABUNDANCE OF MALARIAL MOSQUITOES, CARBONDALE, 1919

A number of writers have raised a question as to the comparative importance of *Anopheles guttulatus* and *A. punctipennis* as carriers of malarial disease, it being believed by some that *guttulatus* is the more active carrier. The preponderance of *punctipennis* in my records indicates that this can hardly be the case. In 1918 *guttulatus* was taken in only four different collections during the year, while *punctipennis* was taken in nineteen. In 1919 seventy-six adults were obtained at Carbondale and only six were *guttulatus*. *Guttulatus* being so rare in Carbondale, I think the other species must be held responsible for most of the malaria present.

Mr. H. R. Carter and associates, of the U. S. Public Health Service,* report that they found *guttulatus* predominating in Alabama and South Carolina in their August and September surveys, and *punctipennis* in spring to June 15 and in fall. They qualify this, however, by saying that in August and September the live water contains most of the *punctipennis* and the bayou water the *guttulatus*. The following table shows the relative numbers of adults of each species collected in Carbondale from May to October, 1919.

	May	June	July	August	September	October
A. guttulatus.....	1	0	1	4		0
A. punctipennis.....	20	35	1	1		13

From this it would seem that the spring and fall results at Carbondale agree with those found in Alabama and South Carolina. The relation in July and August is doubtful, as not enough specimens were obtained for a definite conclusion. A point clearly brought out by the species table (p. 320) is the adaptability of *Anopheles punctipennis* to all types of breeding-places. Both in 1918 and 1919 it was found in all seven; and in June, 1918, and May and June, 1919, it was found in six of the seven types each month. *Aëdes taeniorhynchus* Weidemann has been recorded from Illinois by Dr. Ludlow, but Howard, Dyar, and Knab say that it does not occur in this state as it is supposed not to be found over forty miles from salt water. The species mentioned last in the list given on page 320 is very probably that recorded by Dr. Ludlow, but it is apparently different from *taeniorhynchus*. *Aëdes sylvestris* appears to be chiefly an early species. My records agree in this respect with the statement made by Howard, Dyar, and Knab:† "In the South the species [*Aëdes sylvestris*] partakes more of the character of an early spring species, the majority of the specimens developing early from over-

* U. S. Public Health Service, Pub. Health Bull. No. 79, pp. 11-17, by H. R. Carter, J. A. A. Le Prince, and T. H. D. Griffiths.
† "Mosquitoes of North and Central America," Vol. IV, p. 697.

wintered eggs; but this may be due to the fact that summers are drier, and favorable pools rarer, than they are in the North."

Survey Work in Murphysboro

My procedure in Murphysboro was similar to that at Carbondale. The leading physicians whom I interviewed gave two hundred to four hundred cases of malaria as their estimate for an average year. As the population is about eight thousand, this would mean that 2½ to 5 per cent. of the inhabitants are treated for malaria annually. A map of the township was traced, and all possible breeding-places were located; and examinations and collections were made, but, owing to other occupations, not very continuously throughout the season.

BREEDING-PLACES

Class I, Cattail Swamps.—No breeding-places of this type are near enough to affect Murphysboro. A large number which are in some respects similar, I am placing in a separate class (No. IX).

Class II, Marsh.—Not found in Murphysboro or immediate vicinity.

Class III, Ponds.—Railroad embankments very often form ponds by damming up water. One such pond, located close to the Brown shoe factory, I found to be a breeder of Anopheles. Pleasure and amusement parks may be mosquito-breeding grounds; and a few small ponds in the city park in Murphysboro contain Anopheles. In a ravine very close to the high school is a representative of this type (Fig. 11).

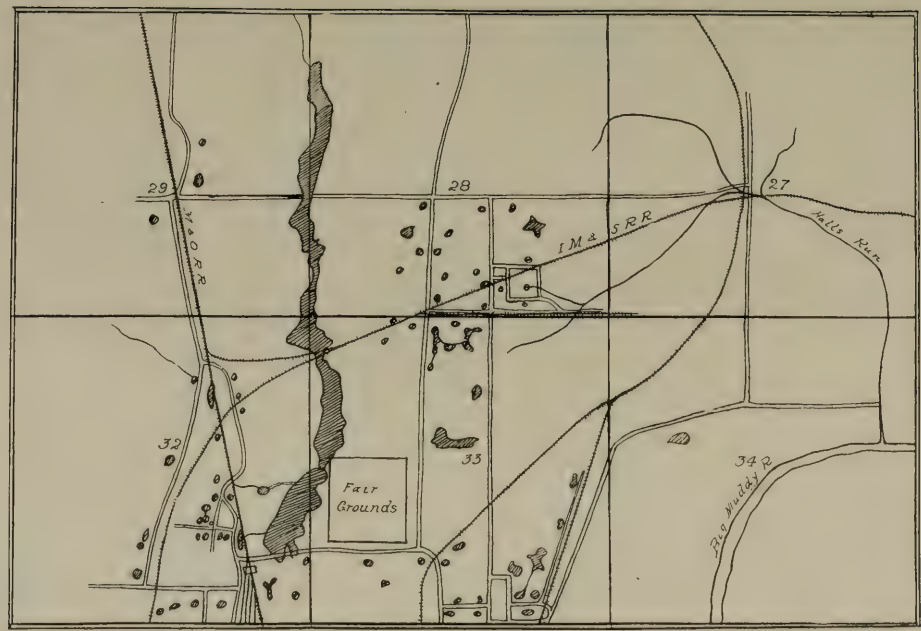
Class IV, Roadside Ditches.—This type is not noticeable in Murphysboro.

Class V, Streams.—Running through the city park is a slow stream (Fig. 12) with banks well covered with grass and affording ideal breeding conditions for Anopheles mosquitoes. The fact that the only park in town includes this stream is deplorable, as it probably accounts for much of the malaria. It should be remembered that a park is very often visited for picnics in the evening, when malarial mosquitoes bite.

Class VI, Open Drains.—One drain in the north end of town is responsible for the production of part of the Anopheles mosquitoes in Murphysboro.

Class VII, Lakes.—The situation at Carbon Lake, belonging to the Country Club of Murphysboro, is very similar to that at Thompson's Lake near Carbondale. Stecher's Lake is much more likely to breed Anopheles, especially because of its grassy edge (Fig. 13). Under the culvert at one end of the lake I was often able to make large collections of Anopheles adults.

Class VIII, Temporary Flooded Land.—This type is caused by overflow of the flats of the Big Muddy River, at the south edge of town. The high water lasts, however, for so short a time that I doubt whether many of the mosquitoes of Murphysboro can be traced to this source.



Sink-holes north of Murphysboro.

Class IX, Sink-holes.—The last permanent type is composed of breeding-places caused by the sinking of the ground over abandoned coal mines after the props have rotted down. These sink-holes fill with water, and grass and cattails spring up around the edges and sometimes in the center of the pond. Fig. 14 shows one of them. Fig. 15 was taken during the drouth of midsummer, 1919, when the water was everywhere very low. In many sink-holes the water-line had receded so far from the cattail growth that no protection was left for the mosquito larvae. As a consequence of this and of the concentration of predaceous insects and animals, there were practically no mosquito larvae in such situations. The significance of this fact will be brought out later under a discussion of control measures. The accompanying map shows the remarkably large number of these sink-holes (eighty in all) just north of Murphysboro. A considerable number are to be found in the vicinity of the Mobile and Ohio Railroad shops and yards, and Dr. O. B. Ormsby, of Murphysboro, told me that a rather high percentage of the railroad cases in town were malarial. While my work here could not be made continuous enough to warrant definite statements, these sink-holes are at least probably partly responsible for this condition.

Survey Work in Anna and Jonesboro

Two days in August, 1918, were spent in survey work at Anna and Jonesboro. Previous inquiries as to the average number of malaria cases per year brought surprisingly different replies, as follows: for Jonesboro, 300, 2,000, 50; for Anna, 2,000, 1,500, 150, 600. Only one of these physicians makes the blood tests, and this may account for the widely different estimates, as this is the only method of certain diagnosis. He estimated 600 cases in Anna. One of the oldest doctors there told me that most physicians believe that there is likely to be some malaria in every case they are called upon to treat.

Breeding-places.—A majority of the physicians and of other citizens interviewed expressed the opinion that most of the malarial mosquitoes in the two towns were bred in the bottom-lands of the Mississippi, and I think that this is a source of a part of them. It is a matter of common knowledge in Anna and Jonesboro that when the wind blows steadily from the west and southwest for about two days, swarms of mosquitoes are carried in from the lakes and sloughs in the bottoms. These invasions are always followed, the doctors all told me, by a marked increase in the number of malaria cases. The fact that the nearest of these bottom-land breeding-places is six miles from town will serve to show the distance which mosquitoes may be carried by the wind. It also appears to be a matter of common knowledge that since the recent drainage of many of the sloughs and lakes, the severity of these periodic attacks by mosquitoes has been greatly lessened. It should be remembered that many residents of Anna and Jonesboro go to the Mississippi bottoms to fish

and hunt, or to look after their farms, and that they may thus contract malaria away from the towns.

There are, however, other much closer, and probably more important sources of malaria. In both Anna and Jonesboro small streams running in and close to town contained Anopheles in considerable numbers, and I do not doubt that these are among the chief sources of mosquitoes. Ponds in the fair-grounds of both towns and two other small pools examined, also showed Anopheles, and it is quite likely that such places furnish most of the mosquitoes in the vicinity.

Survey Work at Scott Field, Belleville

Upon request of Captain Bayliss, principal medical officer at Scott Aviation Field, investigations of the mosquito situation around the camp were made in the summer of 1918. This field has been located very close to a large swamp, which at one point was only a quarter of a mile away. There was an abundant growth of vegetation to shelter mosquito larvae, and those of Anopheles were found in considerable numbers. The ordinary swamp-land growth (Fig, 16) of trees, brush, and weeds was quite rank, and arrowhead especially abundant. Owing to an excessively dry summer the swamp practically dried up later, and no further examinations of it were made.

Within a few rods of the field boundary is a slow stream (Fig. 17). This was breeding Anopheles, and they were even more abundant a little later when the stream was reduced by the drouth to a series of pools. There was no current at that time to hinder development, and there was grass enough around the edges for protection.

Scouting Work in other Places

General scouting work was done in and around Thebes and Cairo, and in Williamson county, and additional types of breeding-places were observed in these places. Some inquiries were made as to the extent of malaria, and some maps were made.

Control Measures

1. *Drainage.*—Beyond a doubt, drainage is the most effective measure for the control of mosquitoes, with the exception of those living in running streams; and the first step in a clean-up campaign is the elimination of standing water.

At Carbondale a special effort was made to bring this subject to the attention of those in charge of property containing standing water. The opinion of the surveyors that the cattail swamps north of town could be drained into a tributary of Crab Orchard Creek by a ditch a little over a quarter of a mile long was laid before the division superintendent of the Illinois Central Railroad Company at Carbondale.

The presence of Anopheles in the pond at the Normal School was brought to the attention of the president, and the subject of drainage was broached. Objection was made that the water might be needed in case of fire, and I then suggested cleaning the edges of the pond as the next most efficient measure of control.

The importance of draining the marsh near the negro school was impressed upon the president of the city Board of Health, and he took the matter up with the City Commissioners.

2. *Cleaning the Edges of Breeding-places.*—Where drainage is impracticable, the next most effective means is cleaning the edges of protective vegetation. While some species of mosquitoes do not seem to care particularly for shade and protection, those of the genus Anopheles do, and thrive much better in it. Insects, small fish, and other animals which prey upon mosquitoes, have a much better opportunity to find and catch the wigglers when the protecting growth is removed. That they may often be exterminated by such means I am satisfied from the examinations of the Murphysboro sink-holes in the dry months of 1918 already referred to and illustrated in Fig. 15. As has been suggested, this method is especially useful with small streams, which of course can not be drained, and on which the use of the third remedy (oiling) is difficult. Open drains through town, which are not at all uncommon in southern Illinois, if they can not be replaced by covered drains, should at least be carefully cleaned. They should be covered, if possible, as this both removes protection and usually prevents the laying of eggs. If drains must be left open through town their beds should be so graded that the water will not form pools in dry weather.

A special effort was made in Carbondale to advise the city authorities on this subject through the Board of Health, and during Health Promotion Week illustrated talks were made by the writer on the local situation and all phases of control. It should be remembered that the edges of a pond or ditch should not be cleaned just once, and then left for the plants to grow up again, but that they should be kept clean continuously. Neglect of this precaution was illustrated in Thompson's Lake when it was lowered eight feet to destroy a growth of pond-lilies and cattails troublesome in boating. Much of the growth was killed, but so many plants grew up again that Anopheles bred almost as abundantly as before.

3. *Oiling.*—Oiling may be used to smother the mosquito larvae in the water, in conjunction with cleaning operations. The surface film thus formed prevents the larvae and pupae from reaching the air necessary to their respiration. A rate of application commonly recommended is an ounce of oil to fifteen square feet of water surface. Prof. W. B. Herms, of California, finds that application of oil by the dipperful is very wasteful and uses a knapsack sprayer instead. Flowing streams may be oiled by means of drip cans so arranged that oil will drip from them at a rate of about twenty drops a minute. A mixture of kerosene with a heavy fuel oil, half and half, is better than pure kerosene, because it spreads

well, is lasting, and resists the wind, while kerosene alone is easily blown aside. Oiling should be done every twelve days during the heat of the summer, but less frequently in spring and fall, according to temperature, which determines the rate of mosquito development. However, if it is desired to control other mosquitoes than the malaria carriers, an application once a week is necessary. Vegetation should first be removed, if possible, from the edges of the breeding-places, because it prevents the maintenance of a perfect film. Especially when a wind blows the plants back and forth, the surface film can not be kept unbroken.

4. *The Use of Larvicides.*—A larvicide as used in mosquito control is a chemical put into the water and which mixes thoroughly with it to kill the larvae. It has been found satisfactory in some situations, especially in yellow-fever control work in the Canal Zone. The larvicide most commonly recommended is one tested out by the Ancon Hospital Board of Health Laboratory in 1911. The stock solution is made as follows:* "150 gallons of carbolic acid is heated in a tank to 212° F. Then 150 pounds of powdered or finely broken resin is poured in. Thirty pounds of caustic soda are then added, and the solution is kept at the same temperature until a perfectly dark emulsion without sediment is formed, constantly stirring after the resin is put in. One part of the emulsion to ten thousand of water is said to kill the larvae in less than one half hour, and one part to five thousand in five to ten minutes."

5. *Screening.*—Screening houses to keep out mosquitoes is very common, yet there are many houses, especially in the country, which are not protected by screens, and too frequently those used are torn, or do not fit tightly, really acting as traps, allowing the mosquitoes to get into the house but providing no exit which can be readily found. The malarial mosquitoes begin to bite at dusk, and if one keeps inside of a properly screened house in the evening, he is quite safe.

6. *Fumigation.*—Fumigation is of some value when mosquitoes get into a house or tent. In such cases burning powdered sulphur or a heap of pyrethrum powder should clear them out. Cresol, about four ounces to a thousand cubic feet of space, heated in a shallow vessel until vaporized, is often recommended.

7. *Use of Palliatives on Mosquito Bites.*—Those who are especially sensitive to mosquito bites will profit by recent experiments of Dr. H. E. Ewing.* He found rubbing helpful in diffusing the poison. Although it increased the itching at first it presently caused it to cease. Strong alcohol and strong ammonia were more useful than dilute alcohol, dilute ammonia, soap, or bay rum.

Summary

1. Malarial disease is common in southern Illinois, causing some loss of life and a large loss of time and money.

* Farmers' Bull. 444, U. S. Dept. Agr.
* "The Use of Palliatives for Mosquito Bites," Journ. Econ. Ent., Vol. XI, pp. 401-404.

2. Malaria is transmitted from man to man only by the bite of certain kinds of mosquitoes, which are common in the southern part of the state.

3. The larvae of these mosquitoes are found in all kinds of waters, but are most abundant in a fairly clean still water with an abundance of grass and weeds for their protection.

4. Control measures are (1) the drainage of breeding-places; (2) keeping the margins clear of vegetation; (3) maintaining a film of oil upon the water; (4) the use of larvicides for killing the larvae; and (5) the screening of houses. Additional, but much inferior, measures are (6) the fumigation of rooms to destroy adult mosquitoes; and (7) the use of repellents to drive them away. Palliatives may be used to diminish the effect of their bites.

PLATE XXXI

FIG. 1. Portion of cattail swamp.

FIG. 2. Near view of cattail growth.

PLATE XXXII

FIG. 3. Marsh; grass and weeds predominating.

FIG. 4. Open drain through Carbondale. Prolific breeder of malarial mosquitoes.

FIG. 5. Open drain through Carbondale. Mosquito-breeding abundant.

FIG. 6. Open drain through Carbondale. In neighborhood of school building.

FIG. 7. The open drain shown in Fig. 6. Abundant growth of marginal vegetation.

FIG. 8. Pond on campus of State Normal School at Carbondale. Larvae of malarial mosquitoes found within twenty feet of dormitory shown in the picture.

PLATE XXXV

FIG. 9. Pond on Normal School campus, Carbondale, showing protecting vegetation around the edges.

FIG. 10. Thompson's Lake, showing protecting marginal vegetation.

FIG. 11. A pool in Murphysboro.

FIG. 12. Stream in city park at Murphysboro. Abundant protecting vegetation along the banks.

PLATE XXXVII

FIG. 13. Stecher's Lake, Murphysboro. The source of many of the malarial mosquitoes of the town.

FIG. 14. Sink-hole near Murphysboro, formed by sinking of the ground over abandoned mine.

PLATE XXXVIII

FIG. 15. Sink-hole in very dry weather. Edges clear of protecting vegetation.

FIG. 16. Swamp at Scott Aviation Field, near Belleville.

PLATE XXXIX

FIG. 17. Mosquito-producing creek, Scott Aviation Field, Belleville.

ARTICLE XII.—*New Species and Varieties of Phyllophaga.* BY JOHN J. DAVIS, Riverton, New Jersey.

Among the many collections of May-beetles received from entomologists throughout the country have been found several apparently new species and varieties. Requests from the collectors for names which they could use in writings prompt the author to present the following descriptions.

I wish to acknowledge my indebtedness to Dr. Henry Fox for the drawings of the genitalia of *perlonga, mississippiensis, pearliae, foxii, impar,* and *comosa,* and to Mr. R. E. Snodgrass for the detail drawings of the anal segment of the larvae of *perlonga* and *mississippiensis.*

PHYLLOPHAGA PERLONGA, n. sp.

This large characteristic species is typical of the fusca group and apparently is nearest *P. drakii* (*grandis* Sm.) and *P. karlsioei* Linell, but is distinct from both species. It has been designated in the writer's determinations as new species "a".

The species is rather large, measuring 22 to 25 mm., with elongate body, rufocastaneous to almost piceous, thorax shining, elytra dull to moderately shining. Clypeus slightly emarginate, the border moderately reflexed, surface moderately but not closely punctate, front similarly punctate. Thorax widest at base, sides nearly parallel posteriorly, conspicuously arcuate anteriorly, margin entire, disc with feeble not closely placed punctures and with an inconspicuous smooth median line. Elytra with punctures similar to those of thorax but slightly rugulose at middle, costae inconspicuous. Metasternum rather densely hairy. Abdomen shining, sparsely and finely punctate. Claws curved, the tooth median, always noticeably stronger in the female.

Male.—Antenna 10-segmented, the club about as long as the stem, abdomen broadly flattened, the penultimate segment with a short, strongly arcuate ridge bordered with moderately long fine hairs, projecting in the manner of a ledge but not reaching to the posterior edge of the segment, the last segment rather strongly impressed, forming a cup-shaped depression. Fixed spur of hind tibiae approximately two thirds the length of the outer spur. The claspers are dissimilar and quite characteristic (Pl. XL, Fig. 1–4).

Female.—Antenna with club short, about half the length of the stem. Penultimate segment transversely impressed near the posterior ventral margin. The pubic process similar to that of *P. drakii* (Pl. XL, Fig. 5).

Grub.—The larva is characteristic of the genus. Figure 1, showing the arrangement of the two rows of spines and surrounding hairs and spines on the under side of the last abdominal segment, suffices for description.

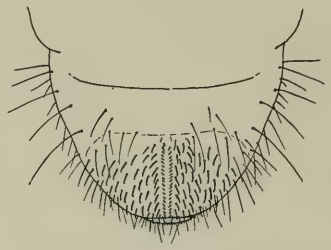


FIG. 1. Under side of anal segment of larva of *Phyllophaga perlonga*, n. sp.

Habitat.—We have this species represented by five or six hundred specimens collected by Prof. R. W. Harned and his assistants and students, at Agricultural College, Miss., March 19 to June 21, with isolated records for July and August, the period of greatest abundance being March and April. We have seen specimens from Greenville, Shubuta, Starkville, and West King Junction, Miss., and from Gum Springs, Clark Co., Ark., all of which were also collected by Professor Harned and his assistants. This species was collected at Clarksville, Tenn., from April 16 to May 25 in 1917 by Dr. Henry Fox, and from April 2 to May 8 in 1918 by Fox and Max Kisliuk, and at Knoxville, Tenn., May 8 to 10, 1916, by G. G. Ainslie and C. C. Hill. In most cases the beetles were collected at lights, but a few, collected at Agricultural College, were taken on pecan, elm, and hickory, and several at Clarksville were found on elm and honey locust.

PHYLLOPHAGA FRATERNA Harr., var. MISSISSIPPIENSIS, n. var.

The above variety belongs to the fusca group according to Horn's synopsis. It has been designated in the writer's determinations as new species "b".

About the size of the largest specimens of *P. fraterna*, varying in length from 18 to 21 mm. and averaging 20 mm., rufocastaneous to piceous, the darker forms predominating, only moderately robust, shining. Clypeus acutely, moderately deeply emarginate, border moderately reflexed, densely punctate, front similarly punctate. Thorax apparently widest at middle, obtusely angulate, margin indistinctly crenate, the punctures only moderately dense and sometimes slightly irregularly placed. Elytra with incon-

spicuous punctures, somewhat rugulose in middle, submarginal costae indistinctly visible on distal half, distal costae moderately distinct. Pygidium not closely punctate, the punctures not clearly defined. Metasternum not densely hairy, finely and rather densely punctate Claws curved and with a strong median tooth in both sexes.

Male.—Antennal club nearly as long as the stem. Abdomen narrowly flattened at middle, penultimate segment with a transverse rugulose area which is scarcely elevated. Last segment concave on median ventrum, smooth except for a few papilla-like elevations near posterior side of concavity. Fixed spur of the hind tibia rather short and broad, being about one half the length of the outer spur. Genitalia large, the left clasper being especially large (Pl. XLI, Fig. 6–9). They closely resemble those of *P. fraterna*, even in the tendency to a notch in the posterior margin of the left clasper.

This variety differs from the typical *fraterna* especially in being larger, and in having relatively larger genitalia and larger antennal club.

Female.—Antennal club very small, as short or shorter than the funiculus. Penultimate with a transverse impression on the under side near the posterior border. The genitalia are strikingly like those of typical *fraterna*, and are sufficiently illustrated in Figures 10 and 11, Plate XLI.

Grub.—The ventral surface of the last abdominal segment is shown in Figure 2. We have compared this grub with that of *P. fraterna*, and find them apparently separable: The two rows of spines on the under side of the last abdominal segment are similar but the surrounding hairs

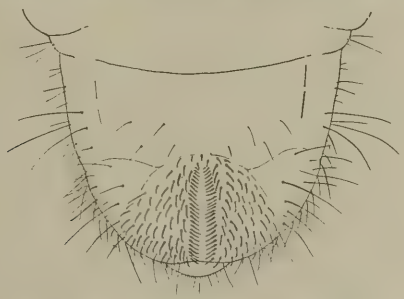


FIG. 2. Under side of anal segment of larva of *P. fraterna*, var. *mississippiensis*.

and spines show an apparently constant difference, those of typical *fraterna* being more sparsely placed, and consequently there are fewer spines, and the anterior spines and hairs being less robust.

Habitat.—Several hundred specimens of this variety have been examined, all of which were collected in Mississippi by Prof. R. W. Harned or his assistants excepting the collections at Greenwood, which were made by Mr. J. M. Langston. The collection localities include Agricultural College, Kiln, Greenwood, Caesar, Ellisville, Forkville, and Starkville, Miss.; the food plants of the beetle include poplar, elm, hickory, black oak, plum, apple, and pecan—the latter apparently preferred; and the dates of collection range from March 19 to June 4, April being the period of greatest abundance.

Phyllophaga pearliae, n. sp.

This species belongs to the fusca group according to Horn's synopsis, but the genitalia are quite distinct from all recorded species. It has been designated in the writer's determinations as new species "c".

The specimens before me are moderately shining, quite variable in color, ranging from reddish brown to almost piceous, the lighter colored specimens with the head and thorax darker. Clypeus densely punctate, narrowly reflexed, moderately deeply and obtusely emarginate, front similarly punctate. Thorax moderately punctate, the punctures fairly uniform and distinct, noticeably narrowest at front, very slightly wider at base than at middle, margin plainly crenate but not conspicuously so. Elytra with punctures finer and more closely placed than on thorax, sutural coxae well marked, the others wanting or scarcely visible. Pygidium with punctures indistinct. Metasternum with hair moderately sparse and short. Claws arcuate, strongly and equally toothed at middle in both sexes. Length, 18 to 20 mm.

Male.—Antenna 10-segmented, the antennal club as long as stem. Abdomen flattened at middle, the penultimate segment depressed along the posterior border and with a slight but noticeable transverse ridge in front of the depression which is more abrupt at sides, the last segment concave in middle. Fixed spur of hind tibia short and stout, being half, or less, the length of outer spur. The genitalia distinctive, claspers dissimilar, the left being large, the right smaller and with a characteristic hook, as illusrated. (Pl. XLII, Fig. 12–15.)

Female.—Antennal club about half the length of the stem. Penultimate ventral segment with a linear transverse impression near the posterior margin. The genitalia characteristic, and well illustrated in Figures 16 and 17, Plate XLII.

This is a typical bottom-land species and was fairly common in the collections of Dr. Henry Fox in 1917 and of Fox and Kisliuk in 1918 in the Red River bottoms at Clarksville, Tenn. They collected it from April 29 to June 11 on elm (? American), winged elm, buttonwood, willow, and honey locust, by far the greater number being taken on honey locust. Mr. D. G. Tower collected a specimen of this species May 24, 1915, under a log in a woods at Princeton, Ind., and the writer found a

number of individuals on walnut and honey locust May 21, 1913, near Louisville, Ky., in an area not far back from and little elevated above the Ohio River.

The writer dedicates this species to his wife in testimony to her philosophical consideration of the continuous nightly collecting trips necessary to a study of the Phyllophagae, and of the equally necessary 2 a. m. luncheons which were invariably awaiting the collector's return.

Phyllophaga forsteri Burm.

The species which the writer has designated in his determinations as new species "d", is apparently *P. forsteri (=P nova)*, a species quite variable. All which have been determined as n. sp. "d" were collected in Florida.

Phyllophaga forbesi Glasgow

The species referred to by the writer in his early determinations as new species "e" has since been described by Mr. R. D. Glasgow as *P. forbesi.**

Phyllophaga soror n. sp.

This small species, which belongs to the quercus group and runs to the species *affabilis* in Horn's synopsis, is distinct from that species but resembles *clypeata* in genital characters. It differs from the latter species in the emarginate clypeus, and there is a slight but constant difference in the genitalia of both sexes. This species has been designated in the writer's determinations as new species "f".

Body oblong, rufotestaceous or darker, the thorax usually more of a reddish brown, with the head darker, surface moderately shining. Clypeus broadly emarginate, margin moderately reflexed, punctures moderately close, front very slightly more punctate. Thorax moderately densely punctate, sides regularly arcuate, not angular, widest at middle and somewhat narrowed at front, less so at base, margin entire and with sparsely placed ciliae. Elytra with moderately dense punctures, the sutural and discal costae moderately prominent, the submarginal ones indistinct or absent. Pygidium with fine, sparsely placed punctures. Claws with tooth of moderate size and basal in male; larger and median in female. Metasternum sparsely hairy. Length, 13 to 15 mm.

Male.—Antenna 9-segmented, the club noticeably shorter than the stem. Abdomen flattened at middle, the last segment with a transverse elevated ridge near anterior margin, broken in the middle with a concavity. Inner spur of hind tibia free and about one half or less the

* Bull. Ill. State Lab. Nat. Hist., Vol. XI (Art. V), p. 378.

length of the outer spur. The genitalia with claspers symmetrical and simple (Fig. 3–5).

Female.—Antennal club very small and shorter than the funiculus. The pubic process is a flat broad plate and deeply notched at the tip (Fig. 6).

Habitat.—Collected at Raleigh, N. C., July, 1916, by R. W. Leiby, and at Columbia, S. C., June 26, 1914, by P. Luginbill and A. H. Beyer.

Genitalia of *Phyllophaga soror*, n. sp.

FIG. 3, right clasper; FIG. 4, dorsal view of same; FIG. 5, front view of male genitalia; FIG. 6, pubic process of female.

PHYLLOPHAGA FOXII, n. sp.

This species belongs to the fusca group. In many respects it resembles *fraterna* and in certain characters it approaches *infidelis*, but is apparently quite distinct. In the writer's determinations it has been designated as new species "g".

Body rufocastaneous to piceous, in the lighter specimens the head darker, sometimes both head and thorax darker. Clypeus moderately deeply emarginate, margin moderately reflexed, coarsely and densely punctate, front slightly less densely punctate. Thorax narrowest at front, the width at middle and at base subequal, sides somewhat angulate, margin indistinctly crenate, sparsely ciliate, punctures moderately sparse and slightly irregular in distribution. Elytra with punctures finer but more densely placed than on thorax, sutural costae distinct, submarginal ones evident but indistinct, especially the distal half. Pygidium with a moderate number of indistinct punctures. Hairs on metasternum moderately sparse. Claws arcuate, with strong median tooth in both sexes. Length, 16.5 to 18 mm.

Male.—Antenna 10-segmented, the club nearly as long as the stem. Abdomen flattened at middle, penultimate segment granulate in middle

with an oblique ridge or tuberosity on either side, last segment with a transverse oval depression. Inner spur of hind tibia short and stout, the outer more slender and fully twice as long. Genitalia resemble those of *infidelis* in many respects but are also constantly different (Pl. XLIII, Fig. 18–21).

Female.—Antennal club about as long as the funiculus. Last ventral segment broadly emarginate. The pubic process is quite different from that illustrated by Smith for *P. infidelis,* and resembles the fraterna-rugosa type. The genitalia are sufficiently illustrated in Figures 22 and 23, Plate XLIII.

Habitat.—This species has been collected at Tappahannock, Va., by Fox, and at Columbia, S. C., by Luginbill and Beyer. The Virginia collections were made April 26, 1915, and April 7 to May 2, 1916, and were taken on the following plants: blackberry *(Rubus nigrobaccus),* blueberry (Vaccinium sp.), wild rose (Rosa sp.), persimmon (*Diospyros virginiana),* red oak *(Quercus rubrum),* Spanish oak *(Q. falcata),* and locust *(Robinia hispida).* The South Carolina collections were made April 17 to May 29, 1916, and were taken on persimmon, elder bush, black gum, hackberry, birch, and sour gum.

It is with much pleasure that the writer names this species in honor of Dr. Henry Fox. Dr. Fox has made collections in Indiana, Virginia, Tennessee, and Georgia which are invaluable in our studies of the distribution, food plants, and ecological relations of the Phyllophagae.

Phyllophaga impar, n. sp.

This very interesting species, occurring, according to our records, only in the Carolinas, apparently belongs to the ephilida group of Horn's synopsis, but is quite distinct from all described species belonging to that group. It has been designated in the writers determinations as new species "h".

Body oblong, slightly broadest behind, reddish brown or darker, the surface sometimes shining but usually more or less pruinose, and in one specimen the surface has a dull smoky appearance such as sometimes occurs in *P. prununcula.* Clypeus feebly emarginate, moderately reflexed, shining, with punctures varying from comparatively sparse to moderately closely placed, front similarly punctate. Thorax narrow at front, being little more than half the greatest width, width at middle very little if any less than basal width, punctures moderately sparse. Elytra more coarsely and apparently more closely punctate than thorax, costae, excepting the sutural, indistinct or absent. Scutellum smooth or with a few very indistinct punctures. Pygidium with a moderate number of fine punctures. Metasternum only moderately hairy. Claws strongly arcuate and with a moderately large median tooth. Length, 13 mm.

Male.—Antenna 10-segmented, the club as long as the stem. Abdomen almost imperceptibly flattened on median ventrum, the penultimate

segment without characteristic sculpture. Inner spur on hind tibia short, being less than half the length of the outer spur, which is long and slender. The genitalia are remarkable because of the dissimilarity of the claspers. The right clasper is slender and gives an impression of having been aborted; the left clasper is strongly arcuate. The illustrations (Pl. XLIV, Fig. 24–27) show the characteristics of the genitalia.

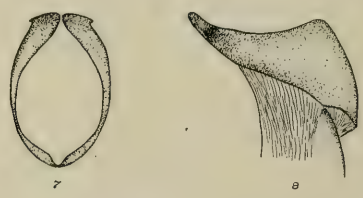
Female.—The female is unknown.

Habitat.—We have this species from only two localities; from Southern Pines, N. C., collected by A. H. Manee, and one specimen, from Columbia, S. C., collected by P. Luginbill and A. H. Beyer in 1915.

Phyllophaga parvidens Lec., var. hysteropyga, n. var.

This variety has the general appearance of *P. crenulata* but is nearest related to *P. rubiginosa* and typical *P. parvidens*, to which species it runs in Horn's synopsis. The male genitalia are identical with those of *P. parvidens*, and there appears to be no constant difference excepting size. This variety is much smaller than any typical *parvidens* which I have seen, being about two thirds the length of that species and not more than half the bulk. Variety *hysteropyga* has many characters in common with *P. pygidialis*, but a comparison with the type of that species shows it to be quite distinct. In the writer's determinations this variety is designated as new species "j".

Body oblong, very little widest posteriorly, brown, head darker, thorax feebly shining, elytra with a slight pruinosity, head and thorax with a moderate number of more or less erect yellowish hairs, the elytra



Genitalia of *Phyllophaga parvidens*, var. *hysteropyga*.
Fig. 7, dorsal view; Fig. 8, right clasper.

with short fine recumbent hair with a few longer erect hairs near anterior end. Clypeus emarginate but not deeply so, the border narrowly reflexed, surface moderately and rather finely punctate, front slightly more densely punctate. Thorax noticeably narrowest at front, the width at middle and base subequal, margin crenate and with moderately long ciliae, surface rather sparsely and finely punctate. Elytra densely punctate,

somewhat rugulose, especially on the median dorsum, recumbent and erect hairs as already described. Pygidium finely and uniformly punctate and set with moderately short recumbent hairs. Metasternum with long hairs rather densely placed. Abdomen slightly pruinose with uniformly short fine recumbent hairs. Claws curved at apex and with a moderate-sized median tooth. Length, 15 to 16 mm.

Male.—Antenna 10-segmented, the club as long as the stem. The genitalia are simple but characteristic, as shown in Figures 7 and 8. Penultimate ventral segment slightly flattened at middle and granulate.

Female.—The female is unknown to the writer.

Habitat.—This species is represented by four males collected by J. D. Mitchell at light, Victoria, Texas, April 6—June 26 (exact date unknown), and we have seen one male collected by W. S. Blatchley at Sanford, Fla., March 25, 1911.

Phyllophaga hirticula Knoch, var. comosa, n. var.

This variety closely resembles typical *P. hirticula*, but may be distinguished by the absence of the rows of hairs on the elytra and the shortness or sparseness of the hairs on the thorax. This character seems to be constant, judging from the long series before me and the statement of the collectors, McColloch and Hayes, who report having collected numbers of this variety without finding any with the rows of hairs on the elytra. The genitalia resemble those of typical *hirticula*, and while there seems to be a constant slight difference in the male genitalia, the difference is so slight as to make it difficult to separate the variety on this alone. The genitalia of variety *comosa* are thicker and more robust than are the genitalia of *hirticula*.

Similar in shape and color to typical *P. hirticula*, being fuscoferruginous to very dark brown, moderately shining, without hairs on elytra except an occasional short one, and only a few on the head and thorax. Clypeus rather deeply emarginate, the margin narrowly reflexed, surface coarsely and densely punctate, front similarly punctate. Thorax slightly narrower at base than at middle, margin finely serrate posteriorly, coarsely so anteriorly, and with short ciliae, surface moderately closely punctate on sides and less so on disc, the punctures more or less irregularly placed, a rather distinct channel along basal margin from the hind angles to near the middle. Elytra with smaller and moderately closely placed punctures, somewhat rugulose at center, no rows of hairs, only an occasional short hair, and margin not fimbriate, sutural costae distinct, submarginal ones indistinct or absent. Pygidium with punctures moderately sparse and not distinct, wider than long, the apex broadly rounded. Metasternum with fine dense punctures and densely clothed with moderately long hairs. Claws arcuate, with a strong median tooth, alike in both sexes. Length, 16.5 to 18.5 mm.

Male.—Antenna 10-segmented, the club not quite as long as the stem. Abdomen flattened at middle, the posterior margin depressed, giving the general appearance of a transverse ridge across the anterior half or two thirds of the segment, which is more abrupt at sides. Last segment with a transverse oval depression on under side. Inner spur of hind tibia moderately short and about half the length of the outer. The genitalia are shown in Figures 28–31, Plate XLV.

Female.—Antennal club short, being about as long as the funiculus. The genitalia are illustrated in Figures 32 and 33, Plate XLV.

Phyllophaga postrema Horn

The writer has had no opportunity to examine the types of *P. postrema* or *P. quadrata* Sm., but a study of our collections indicates that they are identical. The former is known only by the male and the latter by the female.

Types of all the species and varieties described in this paper are deposited in the collections of the Illinois Natural History Survey; paratypes of the same, in the United States National Museum and in the writer's collection; and paratypes of *perlonga, mississippiensis, pearliae, soror, foxii,* and *comosa* have been deposited in the collections of the American Museum of Natural History and of the Philadelphia Academy of Sciences.

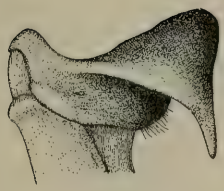
Plate XL

Phyllophaga perlonga, n. sp.

Fig. 1. Left clasper.
Fig. 2. Right clasper.
Fig. 3. Male genitalia, rear view.
Fig. 4. Male genitalia, dorsal view.
Fig. 5. Female genitalia.

(See also text figure, p. 330.)

PLATE XL



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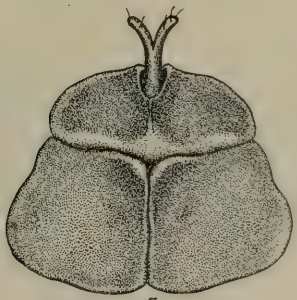

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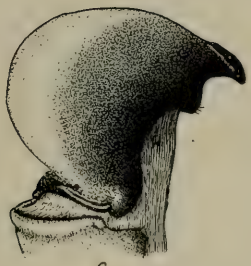
PLATE XLI

Phyllophaga fraterna Harr., var. *mississippiensis*, n. var.

FIG. 6. Left clasper
FIG. 7. Right clasper.
FIG. 8. Male genitalia, rear view.
FIG. 9. Male genitalia, dorsal view.
FIG. 10. Female genitalia, dorsal view
FIG. 11. Female genitalia, side view.

(See also text figure, p. 331.)

PLATE XLI



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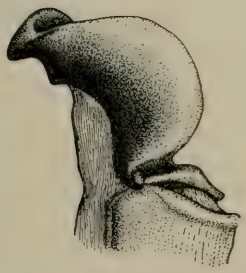

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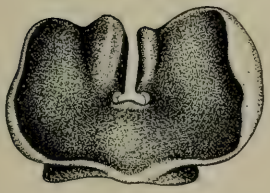

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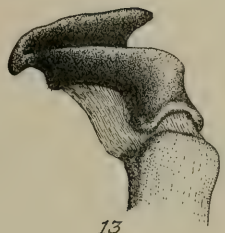
PLATE XLII

Phyllophaga pearliae, n. sp.

FIG. 12. Left clasper.
FIG. 13. Right clasper.
FIG. 14. Male genitalia, rear view.
FIG. 15. Male genitalia, dorsal view.
FIG. 16. Female genitalia, dorsal view.
FIG. 17. Female genitalia, side view.

PLATE XLII

12



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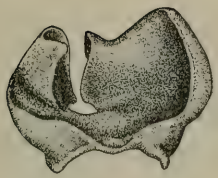

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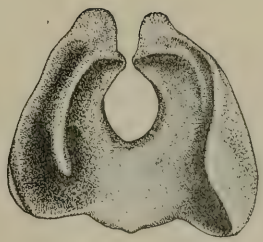

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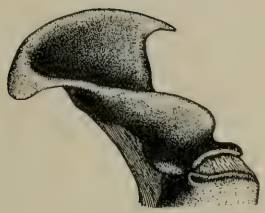
PLATE XLIII

Phyllophaga foxii, n. sp.

FIG. 18. Left clasper.
FIG. 19. Right clasper.
FIG. 20. Male genitalia, rear view.
FIG. 21. Male genitalia, dorsal view.
FIG. 22. Female genitalia, dorsal view.
FIG. 23. Female genitalia, side view.

PLATE XLIII

18



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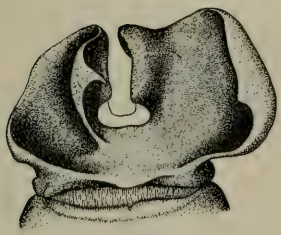

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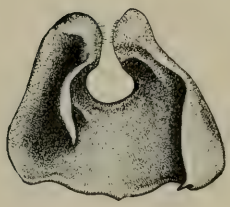

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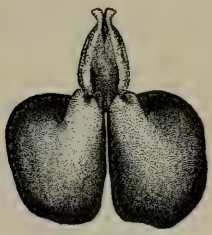

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PLATE XLIV

Phyllophaga impar, n. sp.

FIG. 24. Left clasper.
FIG. 25. Right clasper.
FIG. 26. Male genitalia, rear view.
FIG. 27. Male genitalia, dorsal view.

Plate XLIV

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Plate XLV

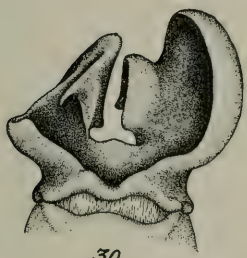
Phyllophaga hirticula Knoch, var. *comosa*, n. var.

Fig. 28. Left clasper.
Fig. 29. Right clasper.
Fig. 30. Male genitalia, rear view.
Fig. 31. Male genitalia, dorsal view.
Fig. 32. Female genitalia, dorsal view.
Fig. 33. Female genitalia, side view.

PLATE XLV

28

29



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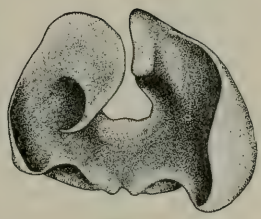

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ARTICLE XIII.—*Further Tests of Dry Sulfur Compounds for the Control of the San Jose Scale.* BY WESLEY P. FLINT.

INTRODUCTION

During the season of 1919 a series of experiments for the control of the San Jose scale was conducted in two orchards on the west side of the state. The object of these experiments was to make a thorough test, under field conditions, of several widely advertised dry sulfur compounds intended for the control of the San Jose scale. A description of these experiments and the results have been published in Experiment Station Circular No. 239, this work being conducted by W. S. Brock, of the Horticultural Department of the University of Illinois, and the present writer. During the season of 1920 the work in the Quincy orchard was continued and slightly enlarged, but that in the Barry orchard was abandoned for lack of funds.

The dry sulfur compounds, especially the dry lime-sulfurs, have several advantages over the commercial lime-sulfur solutions, for orchard use. Some of these advantages are that the dry material is not subject to leakage; does not deteriorate with freezing; is much cheaper to ship and easier to haul; and is much handier to work with, especially for the small orchardists.

For a better understanding of these experiments the description and results of the work done in 1919 are first given in full.

LOCATION AND CONDITION OF ORCHARDS

The orchards selected for the experiments are near Barry, Pike county, and Quincy, Adams county.

The orchard in Pike county is located one and one-half miles west of Barry and contains about forty acres of mature Ben Davis trees. The block selected in the Barry orchard adjoins an Osage hedge which was probably the original source of the scale infestation. The trees nearest the hedge were incrusted and, untreated, would almost certainly have failed to survive the season of 1919. At a distance of two hundred feet from the hedge the infestation was not quite so serious, but many of the limbs were incrusted. The plots were arranged to include each degree of infestation, and were as nearly uniform as possible.

The orchard near Quincy, situated two miles east of the city, on the farm of Wm. Hausemann, consisted of six acres of seventeen-year

old trees of mixed varieties, Ben Davis and Grimes predominating. There was a uniformly heavy infestation of the scale throughout the orchard, all trees showing some limbs incrusted. The majority of these trees would probably not have survived the season of 1920 if no treatment had been given.

Materials Used

The materials used and the strength of each spray were as follows:

Commercial concentrated lime-sulfur 33° Baumé, 1 gallon to 8 gallons of water
Scalecide, 1 gallon to 15 gallons of water
B. T. S., 14 pounds to 50 gallons of water
Niagara soluble sulfur, 12½ pounds to 50 gallons of water
Sherwin-Williams dry lime-sulfur, 15 pounds to 50 gallons of water
Dow dry lime-sulfur, 15 pounds to 50 gallons of water

Time and Method of Application

Barry Orchard.—The sprays were applied March 28, 1919, with a "Bean" duplex power outfit at a minimum pressure of 250 pounds. There was a brisk west wind which made it necessary to use a spray gun in order to make the application from all sides of the trees. The tops of the trees were covered by a rod, and whirlpool disc nozzles were operated from the tower. The gun was operated from the ground.

The weather was warm and the first leaves were beginning to show green. About nine gallons of material were used to each tree.

Quincy Orchard.—The sprays were applied March 27, 1919, with a "Friend" power outfit, using from 250 to 275 pounds' pressure. The tops and upper sides of the branches were sprayed with a gun from the tower, the under sides being covered with a rod used from the ground. A third man stood at a little distance from the sprayer to call attention to any parts of the tree that were missed. In this way, a very thorough application was made to all parts of the trees, about eleven gallons of solution being used per tree.

The weather was warm, with bright sun and a light wind. The leaf buds were just bursting, nearly all of them showing a little green.

Results

The orchards were graded July 21 and 22 by both experimenters, working independently, neither knowing the kind of treatment applied to the plots except in the orchard under his personal supervision. Each tree in a given plot was graded separately, and a general average for the plots was determined. The results were then compared and tabulated as shown in the following table.

San Jose Scale Experiments, 1919

Plot No.	Treatment	Control	
		Barry	Quincy
1	Commercial lime-sulfur solution, 1 gallon to 8 gallons water	Good	Good
2	Niagara soluble sulfur, 12½ pounds to 50 gallons water	Excellent	Excellent
3	B. T. S., 14 pounds to 50 gallons water	Fair	Good
4	Sherwin-Williams dry lime-sulfur, 15 pounds to 50 gallons water	Excellent	Excellent
5	Dow dry lime-sulfur, 15 pounds to 50 gallons water	(*)	Excellent
6	Scalecide, 1 gallon to 15 gallons water	Excellent	Excellent
7	Check: unsprayed		

* Material failed to arrive in time for application.

In the above table the terms used indicate that a plot graded as "Fair" showed a considerable number of live scales present on all parts of the tree and fruit; "Good" indicates scattered living scales fairly easy to find, but not numerous enough to cause marked blemishes on the fruit or injury to the trees; and "Excellent" indicates living scales difficult to find and no blemishes on the fruit.

Additional Work in 1920

In the spring of 1920 the same orchard at Quincy was again treated, plots 1, 2, 3, 4, and 5 being given the same application as in 1919. Plots 6 and 7 were sprayed with Martin-Senour's dry lime-sulfur at the rate of 12½ pounds to 50 gallons of water. A check plot of three trees was left on the east side of the orchard, these trees having been sprayed in 1919 with liquid lime-sulfur, one to eight. The spray was applied on March 29 and 30. The days were warm and bright, with a moderately high wind from the northwest. The leaf buds were just beginning to show the green. The spraying was done with a "Friend" power outfit, using from 200 to 250 pounds' pressure, the spray being applied with two rods, one used from the top of the tank and the other from the ground. All the trees were sprayed as thoroughly as possible.

The orchard was graded on June 11 by five men, working independently, only one of whom knew the treatments which had been given. The plots were again examined and graded on Aug. 11 and Sept. 22, to note any increase in the number of scales. Results of these gradings were compared and tabulated as in 1919.

On Aug. 11, fifty leaves were picked at random from different parts of the trees in each plot, and examined for living scales.

On Sept. 22, one hundred apples on each plot were examined for the presence of the scale. These results may be somewhat misleading from the fact that the number of scales on all of the apples where less than 20%

showed the scale, was very small, very few of the apples being sufficiently infested to cause a blemish.

The results of these examinations are shown in the following table.

Plot No.	Treatment	Fifty leaves examined August 11	One hundred apples examined September 22	Control for season
1	Commercial lime-sulfur solution, 1 gal. to 8 gals. water.....	No scale	20% show scale	Good
2	Niagara soluble sulfur, 12½ lbs. to 50 gals. water.....	Scale on 4	22% show scale	Good
3	B. T. S., 14 lbs. to 50 gals. water.	No scale	16% show scale	Good
4	Dow dry lime-sulfur, 15 lbs. to 50 gals. water.....	No scale	12% show scale	Good to excellent
5	Sherwin-Williams dry lime-sulfur, 15 lbs. to 50 gals. water....	No scale	16% show scale	Good
6	Martin-Senour dry lime-sulfur, 12½ lbs. to 50 gals. water..	Scale on 12	32% show scale	Poor to fair
7	Check: unsprayed.....	Scale on 40	100% show scale	

In addition, a spray was applied to an older orchard composed entirely of 25-year old Ben Davis trees. These trees had been badly neglected and over half of the orchard was dead, the remaining trees being almost entirely incrusted and showing numerous dead branches. This orchard was treated in the following manner:

Plot 1—Commercial lime-sulfur solution, 1 gal. to 8 gals. water
2—Niagara soluble sulfur, 12½ lbs. to 50 gals. water
3—B. T. S., 14 lbs. to 50 gals. water
4—Dow dry lime-sulfur, 15 lbs. to 50 gals. water
5—Sherwin-Williams dry lime-sulfur, 15 lbs. to 50 gals. water
6—Martin-Senour dry lime-sulfur, 12½ lbs. to 50 gals. water
7—Check: unsprayed

This orchard was carefully examined on June 11, and again on Sept. 22. The scale was still numerous on many of the heaviest infested trees, as it would be impossible to clear up this orchard entirely with one treatment. A summary of the results obtained from this grading is as follows.

Plot No.	Treatment	Control for season
1	Commercial lime-sulfur solution, 1 gal. to 8 gals. water..	Good
2	Niagara soluble sulfur, 12½ lbs. to 50 gals. water.....	Fair to good
3	B. T. S., 14 lbs. to 50 gals. water.....	Fair to good
4	Dow dry lime-sulfur, 15 lbs. to 50 gals. water.....	Good
5	Sherwin-Williams dry lime-sulfur, 15 lbs. to 50 gals. water.	Good
6	Martin-Senour dry lime-sulfur, 12½ lbs. to 50 gals. water.	Very poor
7	Check: unsprayed	

The results of two years' work with these materials seem to show that some dry sulfur compounds, if used at sufficient strength, are effective in controlling the San Jose scale. From the results of the past season where Martin-Senour's dry lime-sulfur was used at a strength of 12½ lbs. to 50 gallons of water, it is apparent that these materials should not be used at a less rate than 15 lbs. to 50 gallons of water.

ARTICLE XIV.—*Forest Insects in Illinois. I. The Subfamily Ochthiphilinae (Diptera, Family Agromyzidae).* BY J. R. MALLOCH.

This paper deals with a small group of two-winged flies, or Diptera, belonging to the subfamily Ochthiphilinae, family Agromyzidae, and is intended to serve as an index both to the habits and the systematic relations of the species.

CHARACTERS OF SUBFAMILY

Costa complete, extending to apex of fourth vein; fifth vein not flexed proximad of outer cross-vein; anal vein incomplete; both basal cells present, sometimes the cross-vein at base of discal cell very weak; vibrissae absent; postvertical bristles absent or present, when present convergent; tibiae without preapical bristle; interfrontal bristles absent; orbits never with an anteriorly directed bristle; arista bare or pubescent; sternopleura with one or more bristles; propleural bristle absent; clypeus small.

DISTRIBUTION AND BIOLOGY OF GENERA

This subfamily contains only seven genera. Of these, four are known to occur in Illinois; the other three each contain only one North American species and are more southern in their known distribution. With the exception of the genus Cryptochaetum the genera have not been considered as of economic importance and but little has been published on the biology of the other genera, this paper containing the most complete series of records of the larval habits extant. The predaceous habits of the larvae, which so far as known feed upon aphids and scale insects, give to the species an economic status which does not belong to any other subfamily in the acalyptrate Diptera, the only true aphidophagous larvae in the Cyclorrhapha occurring in the Syrphidae. All species of the genus Leucopis feed on aphids and scale insects, and it is possibly due to their small size that their importance as destroyers of these insects has not been more than casually mentioned in literature.

I present keys to the genera of the subfamily, including the larvae known to me, and keys to all the North American species of the genera Pseudodinia and Leucopis *sens. lat.*

The larvae of Leucopis are subject to attack by chalcid parasites, the imago of the parasite emerging through a ragged hole which it gnaws in the anterior portion of the dorsum of the puparium of the host.

Keys to Genera

LARVAE AND PUPARIA

1. Anal respiratory processes thread-like, one of them at least ten times as long as body, coiled inside of body of host; both larva and puparium internal in host *(Icerya purchasi)*.....*Cryptochaetum* Rondani

— Anal respiratory processes very short and stout, sometimes sessile, not thread-like, and not as long as body; larva and puparium not internal in host.....*(Leucopis, sens. lat.)* 2

2. Body almost cylindrical, not tapered posteriorly, with minute warty or setulose armature; anal respiratory processes sessile, situated much above level of venter and widely separated. Host, *Pulvinaria vitis* L.....
.....*Leucopomyia*, subgen. n.

— Body distinctly flattened ventrally, tapered both anteriorly and posteriorly, usually with minute warty or setulose armature; anal respiratory processes stalked, usually lying close against the surface to which the larva or puparium is adhering.....*Leucopis* Meigen, *sens. str.*

IMAGINES

1. Orbits with one or more pairs of distinct bristles.....2

— Orbits without bristles.....4

2. Head pointed at base of antennae, the face almost horizontal; wings distinctly spotted.....*Acrometopia* Schiner

— Head not pointed at base of antennae, face short and nearly or quite vertical (Pl. XLVI, Fig. 5, 6, 9, 10); wings unspotted.....3

3. Thoracic dorsum with four pairs of bristles (Pl. XLVI, Fig. 2); mesopleura bare; ocellar bristles absent.....*Chamaemyia* Panzer

— Thoracic dorsum with three pairs of bristles (Pl. XLVI, Fig. 1); mesopleura bare; ocellar bristles present.....*Ochthiphila* Fallen

— Thoracic dorsum with two pairs of bristles (Pl. XLVI, Fig. 3); mesopleura with one strong bristle; ocellar bristles present but weak.....
..... *Pseudodinia* Coquillett

4. Arista absent.....*Cryptochaetum* Rondani

— Arista present 5

5. Costa with small setulae on under surface; species glossy blue-black.....
..... *Paraleucopis* Malloch

— Costa not setulose; species densely gray pruinescent.....*Leucopis* Meigen

Acrometopia Schiner

The only described North American species of this genus, *punctata* Coquillett, has been recorded only from Georgia.

Larval habits unknown.

Chamaemyia Panzer

This genus has usually been considered as a synonym of Ochthiphila but it is readily separated by means of the characters cited in the above key to genera.

The only species, *elegans* Panzer, occurs in Europe and has been recorded from New Jersey. There are two specimens in our collection from Illinois: Champaign, July 25, 1889, and Mayview, July 31, 1891 (Terrill).

Larval habits unknown.

Ochthiphila Fallen

There is but one species of this genus in our collection from Illinois, *polystigma* Meigen. It is generally distributed throughout the state, and is apparently as common in this country as in Europe.

I know nothing of the larval habits.

Pseudodinia Coquillett

Key to Species

1. Frons anterior to ocelli, distinctly longer than wide (Pl. XLVI, Fig. 7, 11); tibiae and tarsi yellow.....*polita* Malloch

— Frons anterior to ocelli at least as wide as long; apices of tibiae and the tarsi yellow.....2

2. Frons anterior to ocelli much wider than long; apices of third and fourth veins divergent.....*varipes* Coquillett

— Frons anterior to ocelli as wide as long; apices of veins 3 and 4 not divergent 3

3. Thorax and abdomen polished, almost without pruinescence; last section of fourth vein more than twice as long as preceding section..... .....*nitida* Melander

— Thorax and abdomen shining, with distinct pruinescence; last section of fourth vein twice as long as preceding section.....*pruinosa* Melander

Pseudodinia nitida Melander

Three specimens with data as follows, from Illinois: Urbana, August 30, 1914, and September 3, 1916; and White Heath, July 11, 1915. Taken by the writer.

Larval habits unknown.

Pseudodinia polita Malloch

A common species in some parts of Illinois. Our specimens are from Centerville, August 16, 1914, 5 specimens; White Heath, May 30,

1915, 3 specimens; Muncie, June 3, 1917, and August 15, 1917, two specimens; Augerville, June 6, 1915, 1 specimen; Dubois, May 24 and 25, 1917, 4 specimens; and Carbondale May 15, 1910, 1 specimen. All except the last specimen taken by the writer.

Larval habits unknown.

Cryptochaetum Rondani

The only species of this genus in North America, *iceryae* Williston, does not occur in Illinois. The species was introduced into California from Australia to control the mealy citrus-bug in which the larvae are parasitic. In being an internal parasite the species differs from those of Leucopis, the larvae of the latter being predaceous.

Paraleucopis Malloch

This genus contains but one species, *corvina* Malloch, which does not occur in Illinois so far as we are aware.

Larval habits unknown.

Leucopis Meigen, *sens. lat.*

There are at present in the list of North American Diptera seven species of the genus Leucopis. A key to six of these was published by Dr. A. L. Melander in 1913.* Subsequently Dr. J. M. Aldrich described the seventh species†.

Dr. E. P. Felt recently submitted to me for identification several specimens which belong to an undescribed species which is represented also in the collection of the Natural History Survey, and herein I am presenting a key to all the North American species in the hope that by so doing I may make it possible for students to identify their specimens with more certainty than is possible by using the previously published keys.

I find that there are certain very important chaetotaxic differences between some of the species which warrant me in erecting two new subgenera for the reception of two species. It may be that other systematists will consider these segregates entitled to generic rank, but they very closely resemble the species of Leucopis in habitus and markings as well as in larval habits and structure, so that from my point of view the placing of the species in subgenera is more appropriate than either placing them in the same genus or erecting genera for them.

Key to Subgenera

1. **Thorax with a pair of strong bristles between the posterior pair of dorsocentrals (Pl. XLVI, Fig. 4)** 2

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* Jour. N. Y. Ent. Soc., Vol. 21, p. 232.
† Jour. Econ. Ent., Vol. 7, p. 404. 1914.

— Thorax without any bristles between the posterior pair of dorsocentrals; ocellar bristles absent.....*Leucopis* Meigen

2. Ocellar bristles absent.....*Leucopomyia*, subgen. n.

— Ocellar bristles present (Pl. XLVI, Fig. 8).....*Neoleucopis*, subgen. n.

Leucopis Meigen, *sens. str.*

Key to Species

1. Third antennal segment yellow; thorax and abdomen without black or brown stripes or spots, basal segment of the latter blackened except on posterior margin..... *flavicornis* Aldrich

— Third antennal segment black.....2

2. Basal two antennal segments yellow, contrasting conspicuously with the black third segment; mesonotum without distinct vittae, usually with 4 pairs of weak dorsocentrals; legs yellow, femora darkened in middle.. .....*pemphigae*, sp. n.

— Basal two antennal segments not conspicuously paler than third; species in other respects not as above.....3

3. Frontal lunule transverse on its upper margin; thorax and abdomen dark gray, thorax not vittate, and with four series of acrostichal setulae between the dorsocentrals, abdomen with basal tergite almost entirely and the second largely fuscous, slightly shining; last section of fourth vein five or six times as long as preceding section; last section of fifth vein almost or quite twice as long as outer cross-vein; male hypopygium with a very long curved central process.....*piniperda*, sp. n.

— Frontal lunule arcuate on upper margin, almost transverse in *simplex;* thorax with more than four series of acrostichal setulae between dorsocentrals; male hypopygium without a long curved central process....4

4. Abdomen with a small central spot and a larger one on each side of it on each of segments two to four inclusive black.....5

— Abdomen with or without a small black central spot on segments two to four inclusive, but without the lateral spots except on second segment..6

5. Thorax with two brown vittae.....*bellula* Williston

— Thorax not vittate.....*maculata* Thompson

6. Frontal orbits well differentiated from interfrontalia, each orbit wider than the latter, the entire frons pale gray, not vittate; genal bristle long; wing-veins 3 and 4 parallel apically, not convergent; tibiae and tarsi yellowish, the former slightly darkened in middle...*orbitalis*, sp. n.

— Frontal orbits poorly defined, not at all differentiated from interfrontalia, and not as wide as the latter, the frons usually distinctly vittate.....7

7. Several minute setulae in front of genal bristle (Pl. XLVI, Fig. 12); penultimate section of fourth vein at least as long as, generally longer than, ultimate section of fifth (Pl. XLVII, Fig. 1); usually one and sometimes two long setulae in front of anterior dorsocentral bristle; fore tibiae and tarsi yellow.....*major*, sp. n.

— No setulae anterior to genal bristle.....8

8. Fore tarsi largely or entirely yellow.....9

— Fore tarsi largely or entirely black.....10

9. Large species, 2 mm. or over in length; thorax with two faint brown vittae; basal abdominal tergite black except along posterior margin, second with two small round black spots, third and and fourth each with a central black spot on anterior margin.....*bella* Loew

— Smaller species, less than 2 mm. in length; thorax without distinct vittae; basal abdominal tergite bronzy fuscous except laterally, second with two large poorly defined bronzy fuscous submedian spots on anterior margin .....*simplex* Loew

10. Entire fore metatarsus yellow; genal bristle very short; frontal lunule setulose; abdomen marked as in *simplex;* veins 3 and 4 parallel apically .....*parallela*, sp. n.

— At most only the base of fore metatarsus yellow.....11

11. Small species, barely over 1 mm. in length; thorax and abdomen lead-gray pruinescent; fore tarsi entirely, mid and hind pairs except base of metatarsi, black.....*minor*, sp. n.

— Larger species, averaging 2 mm. in length, thorax and abdomen whitish gray pruinescent; fore metatarsus yellow at extreme base, the other tarsi with at least the basal two segments yellowish.....*americana*, sp. n.

Descriptions and Records of Illinois Species

Leucopis pemphigae, sp. n.

Male and Female.—Black, opaque, densely whitish gray pruinescent, Frons slightly rufous anteriorly, but only noticeably so when the surface has been wet, in well-preserved specimens densely whitish gray pruinescent; basal two antennal segments yellow, third deep black, slightly gray pruinescent; palpi black. Thorax not distinctly vittate, the areas occupied by the lateral vittae in other species a little darker gray than the remainder of disc. Abdomen slightly testaceous at apex; hypopygium testaceous; basal tergite with two large, rounded, poorly defined brownish fuscous spots, third and fourth sometimes with a small linear dark spot in center at base, second with two small round fuscous spots. Legs testaceous yellow, femora usually darkened on middle. Wings white, veins brownish except at bases. Calyptrae white. Halteres cream-colored.

Frons almost parallel-sided, sparsely hairy, over one third of the head-width at anterior margin; orbits narrower than interfrontalia; third antennal segment higher than long; genal bristle slender. Mesonotum with three or four dorsocentral bristles; about six series of setulae between the dorsocentrals, median setulae not forming stripes except near anterior margin. Hypopygium as in Plate XLVII, Figures 7, 11, and 12. Veins 3 and 4 distinctly convergent at apices; penultimate section of fourth vein about one third as long as ultimate, and longer than last section of fifth vein.

Length, 2 mm.

Type, male, allotype, and five paratypes, Carbondale, Ill., July 6, 1909, reared from larvae from Pemphigus gall. The species is evidently predaceous on the gall-maker.

Specimens emerged as adults July 15 and 27, 1909.

Leucopis piniperda, sp. n.

Male and Female.—Black, opaque, densely gray pruinescent. Frons unicolorous pale gray pruinescent; antennae and palpi black, second segment of former pale gray pruinescent. Thorax not vittate. Abdomen slightly shining; basal tergite almost entirely brownish fuscous, second less broadly fuscous, the dark parts of tergites more distinctly shining than remainder of dorsum; hypopygial forceps testaceous. Legs black, bases of mid and hind tarsi and sometimes the knees in male testaceous, base of fore tarsus and apices of tibiae pale in female. Wings clear, veins fuscous. Calyptrae and halteres yellowish.

Frons a little over one third of the head-width, with sparse, short, erect hairs; orbits almost uniformly wide for their entire length, each about half as wide as interfrontalia; ocelli in an almost equilateral triangle; lunule broadly transverse on its upper margin, nearly bare; third antennal segment higher than long; second segment of arista about four times as long as thick. Thorax with two or three pairs of dorsocentrals; dorsal setulae sparse, about four series between the dorsocentrals, some lying between the posterior pair. Hypopygium small with a very long curved central process, as in Plate XLVII, Figure 2. Wing-veins 3 and 4 almost parallel on their apical portions; last section of fourth vein five or six times as long as preceding section, the latter very much shorter than last section of fifth vein.

Length, 1—1.5 mm.

Type, male, Urbana, Ill., April 29, 1916, in forestry of University of Illinois. Allotype, Urbana, Ill., July 5, 1915, on tree-trunk. Paratype, male, Boulder, Col., August 19, 1918, reared from needles of *Pinus scapulorum* (E. Bethel).

The type and allotype were collected by the writer in the vicinity of pine trees. The larvae are very probably predaceous on aphids occurring on pine.

Leucopis orbitalis, sp. n.

Female.—Black, opaque, densely pale gray pruinescent. Orbits darker than interfrontalia, the latter slightly testaceous; antennae black, second segment conspicuously whitish pruinescent; palpi black. Thorax not vittate. Basal abdominal tergite brownish fuscous except on posterior and lateral margins, second with a pair of large, poorly defined, round fuscous spots, the dark parts slightly shining. Legs yellowish testaceous, coxae and femora largely fuscous, apices of tarsi infuscated. Wings clear, veins brown, pale basally. Calyptrae white. Halteres pale yellow.

Frons flattened, parallel-sided, a little over one third as wide as head, with sparse microscopic hairs; lunule rounded above; each orbit wider than interfrontalia, anteriorly; antennae as in *pemphigae;* palpi smaller than usual; genal bristle long, the area surrounding it nearly bare. Mesonotum with three or four pairs of dorsocentrals, the anterior two or three pairs weak; setulae between dorsocentrals sparse, three or four series, extending to level of posterior dorsocentrals, but irregularly; dorsal setulae not in stripes anteriorly. Third and fourth veins parallel on apical portions, penultimate section of fourth vein about one fourth as long as ultimate, and shorter than last section of fifth.

Length, 2 mm.

Puparium.—Reddish testaceous, slightly shining.

Distinctly flattened on venter, tapered slightly at both ends, depressed at anterior extremity and slightly so at posterior, though convexly so; surface with minute setulose armature, most distinct on anal segments. Anterior respiratory processes minute, black, with about four branches; anal respiratory processes stout, closely adherent to surface of leaf, armed with microscopic setulae, separated by about twice the basal diameter of one process, each less than twice as long as thick.

Length, 2.5 mm.; diameter at middle, .75 mm.

Type and paratype, Dundee, June 7, 1916. Reared from pine twig infested by Kermes.

Leucopis major, sp. n.

Male and Female.—Black, densely whitish gray pruinescent. Interfrontalia when seen from behind dark gray, the orbits almost white; antennae black, basal two segments paler, the second whitish pruinescent; palpi black. Dorsum of thorax with a brown vitta on each side along the lines of dorsocentrals, which extend to posterior margin; no other markings present. Abdomen with first tergite black except laterally, and narrowly so on posterior margin, second tergite with two large round submedian black spots, and a much less distinct dark streak between them which does not extend to posterior margin; third and fourth tergites

with only the central streak. Legs yellowish testaceous, coxae, and femora except their apices fuscous, tibiae in middle and the apical tarsal segment sometimes slightly darkened. Wings clear, costal and first to fifth veins brown. Calyptrae white. Halteres yellow.

Eyes bare; frons distinctly narrowed posteriorly, at vertex less than one third of the head-width, both orbits and interfrontalia with numerous microscopic pale hairs; lunule large, exceeding in size the third antennal segment, regularly rounded above, its upper half hairy; third antennal higher than long; second segment of arista at least three times as long as thick; face concave, receding below; several short setulae anterior to the genal bristle; palpi broad. Dorsum of thorax with rather dense short setulae, the median line almost obliterated; usually three and sometimes four dorsocentrals present, and between them 8 or more series of short setulae which extend almost to posterior margin; scutellar bristles equal in length. Abdominal tergites 1 to 4 in female subequal, fifth short; ovipositor as in Figure 6, Plate XLVII; hypopygium of male as in Figures 4, 8, and 10, Plate XLVII. Legs normal. Wings broad; veins 3 and 4 distinctly convergent apically; penultimate section of fourth vein usually longer than ultimate section of fifth.

Length, 2.5—3 mm.

Type, female, allotype, and four female paratypes, St. Joseph, Ill., May 3, 1914 (J. R. Malloch).

Larval host unknown.

Leucopis simplex Loew

I have before me a series of 6 specimens of this species which I took at Dubois, Ill., May 21—25, 1917, and one from Muncie, Ill., May 24, 1914.

The characters cited in the key to species should serve to distinguish this species from its allies. Male hypopygium as in Plate XLVII, Figure 9.

The larval host is unknown to me.

Leucopis parallela, sp. n.

Female.—Black, densely gray pruinescent, the color of the pruinescence of abdomen paler than that of thorax. Frons lead-gray, orbits paler; antennae black, second segment whitish pruinescent; palpi black. Thorax lead-gray pruinescent, not vittate. Abdomen whitish gray pruinescent, first tergite subshining fuscous except on lateral margins, second tergite with the usual fuscous spots very large, fused centrally and extending to anterior margin, the other tergites unmarked. Legs black, extreme apices of femora, bases and apices of tibiae, entire fore metatarsus, and the mid and hind tarsi except the apical segment yellow. Wings clear, veins brown. Calyptrae white. Halteres white.

Frons at vertex less than one third of the head-width, slightly widened anteriorly, the surface with microscopic hairs; lunule hairy, subtrans-

verse above, not as large as third antennal segment, the latter as long as high; face concave in center; genal bristle very short; palpi slightly broadened. Thoracic dorsum rather densely and evenly setulose on disc, with two pairs of dorsocentrals; basal pair of scutellar bristles shorter than apical pair. Fifth abdominal tergite about as long as fourth. Legs normal. Wings narrow; veins 3 and 4 parallel apically, penultimate section of fourth vein slightly longer than ultimate section of fifth, the latter longer than outer cross-vein.

Length, 1 mm.

Type, Muncie, Ill., July 5, 1914 (J. R. Malloch).

This species very closely resembles *simplex* Loew, but differs in color of legs, in having the third and fourth veins parallel, the fifth abdominal tergite longer, and the genal bristle shorter. Both species have the discal thoracic setulae continued to posterior margin between the dorsocentrals

Larval host unknown.

Leucopis minor, sp. n.

Male.—Differs from the preceding species in having the spots on second tergite small and widely separated, the posterior margin of first tergite gray pruinescent, the legs black, with bases of all tibiae and of mid and hind tarsi yellowish.

Genal bristle larger than in *parallela.* Discal thoracic setulae discontinued proximad of posterior dorsocentral; basal scutellar pair of bristles slightly smaller than apical pair. Veins 3 and 4 subparallel apically; penultimate section of fourth vein distinctly shorter than ultimate section of fifth, the latter much longer than outer cross-vein.

Length, 1 mm.

Type, Dubois, Ill., August 9, 1917 (J. R. Malloch).

A female in poor condition but which appears to belong to this species was taken at Champaign, Ill., July 24, 1889 (Marten and Terrill).

Larval host unknown.

Leucopis americana, sp. n.

Male and Female.—Black, densely grayish white pruinescent, the abdomen in some specimens almost silvery. Frons with the interfrontalia darker than the orbits, appearing vittate; second antennal segment conspicuously whitish pruinescent. Thorax with or without two brown vittae. Abdomen normally as in *major,* the central spots sometimes obsolete. Legs with a larger amount of yellow than in *minor,* the base of fore metatarsus nearly always yellowish.

Third antennal segment higher than long. Discal setulae as in *minor.* Fifth tergite in female very short. Legs normal. Veins 3 and 4 generally slightly but noticeably convergent apically; position of outer cross-vein variable; wing broader than in *minor.*

Length, 2—2.5 mm.

Type, male, allotype, and two female paratypes, Urbana, Ill., June, 1917. Reared from larvae found feeding on aphids on *Spirea vanhouteii* (J. R. Malloch). This series has the thorax vittate.

The puparia of this species, from which the type series emerged, differ from those of *orbitalis* in having the surface except on venter covered with wart-like protuberances which are tipped with minute spines or setulae. These protuberances are not serially arranged and are separated by a little wider space than the width of the base of one protuberance. The empty puparium is yellowish in color, slightly shining, with a pale brownish vitta between median line and dorsolateral margin. In form it is more robust than that of *orbitalis* and has a slight but evident longitudinal depression along each side, so that the portions dorsad and ventrad of the depression form rounded elevations. Anterior respiratory organs minute, with a few microscopic apical filaments; posterior respiratory organs pedunculate, about three times as long as their basal diameter, separated by a distance equal to their length, their surfaces warty, apical filaments very minute, apparently 4 or 5 in number.

Length, 3 mm.; greatest width, 1 mm.

This species is by far the commonest of the genus in the state, occurring in all the localities in which I have collected. It has previously been referred to in literature as *nigricornis* Egger, but I consider it inadvisable to use the name of a European species for one taken in this country until a very careful comparison of the American and European specimens has been made.

I have before me a very large number of specimens which I consider belong to this species. Those with larval data are as follows: 2 specimens, reared from larvae found feeding on aphids on black locust, Chicago, Ill., September 18, 1908 (J. J. Davis); 1 specimen, reared from a larva found feeding on aphids on *Spirea vanhouteii*, Urbana, Ill., June 25, 1916 (J. R. Malloch); 2 specimens, one with and one without vittae on thorax, reared from larvae found feeding on aphids on apple, America, Pulaski Co., Ill., June 30, 1916; 4 specimens, reared from larvae found feeding on *Aphis rumicis* on thistle, Chicago, Ill., August 30, 1908 (J. J. Davis).

The other specimens in our collection bear no data as to larval foodhabits but are from the following localities: Urbana, Champaign, St. Joseph, Muncie, Monticello, Ashley, Meredosia, Algonquin, and Waukegan.

Leucopomyia, subgen. n.

This subgenus differs from Leucopis in the larval stage in having the body cylindrical and evenly rounded at the posterior end, the anal respiratory processes sessile, situated high above the ventral level and widely separated, and the surface of the body with but indistinct spinose armature. The adult differs in having praescutellar acrostichal and no ocellar bristles.

Genotype, *Leucopomyia pulvinariae*, sp. n.

LEUCOPOMYIA PULVINARIAE, sp. n.

Male and Female.—Black, opaque, densely pale gray pruinescent. Antennae black, basal two segments brownish, grayish pruinescent, third segment slightly brownish on inner side at base; palpi yellow; frontal triangle, orbits, and lunule whitish gray; ocelli reddish. Mesonotum with two broad brown sublateral vittae which do not extend to posterior margin, the submedian vittae pale gray and indistinct. Abdomen with basal tergite except its posterior margin black, second with a pair of black spots at base in center, third and fourth each with a rather indistinct black median spot at base in center. Legs yellowish testaceous, the femora except apices dark gray. Wings whitish, veins, except sixth, pale brown except at bases. Calyptrae white. Halteres cream-colored.

Frons above antennae one third of the head-width, narrowed posteriorly, at vertex about two thirds as wide as at anterior margin; ocelli in an equilateral triangle; each orbit one third as wide as interfrontalia, densely hairy; ocellar triangle extending to anterior margin of frons, usually densely hairy; lunule large, rounded above, the surface with some minute hairs; third antennal segment not as long as wide; second segment of arista about four times as long as thick; face slightly receding; genal bristle strong. Thoracic dorsum rather densely setulose, at middle with about eight series of setulae between the vittae, the median setulae not forming two distinct stripes except near anterior margin; a very strong pair of praescutellars present; sometimes there are three pairs of dorsocentrals present, the anterior pair weak. Abdominal tergites subequal. Legs stout, without bristles except at apex of mid tibia on ventral surface; the fore femur of male with a rather dense fringe of minute setulae on anteroventral surface. Third and fourth veins with apices slightly convergent, penultimate section of latter nearly half as long as ultimate; outer cross-vein about three fourths as long as last section of fifth vein.

Length, 2.5 mm.

Puparium.—Reddish brown, opaque.

Almost cylindrical, very indistinctly flattened on ventral surface, tapered on thoracic segments, where it is depressed on dorsum. Surface with very minute setulose armature which is most noticeable, but only under a very high-power lens, at posterior extremity on dorsum. Anterior spiracles very small. Posterior spiracles sessile, distinguishable only under a strong magnification, situated well above the rounded caudal extremity, forming with the small anal orifice an almost equilateral triangle.

Length, 3 mm.; diameter, 1 mm.

Type, male, allotype, and 10 paratypes, Shushan, N. Y., July 6, 1916, No. a3076, New York State College. Paratypes: female, Chicago, Ill., spring, 1907; male, Algonquin, Ill., July 4, 1892. Both the New York specimens and the one from Chicago were reared from larvae found feeding on the cottony maple-scale (*Pulvinaria vitis* Linné).

I have figured the hypopygium of the male last mentioned, which appears to present in the shape of the dorsal plate, with the truncate notch at its apex, quite a different form from other species of the group (Pl. XLVII, Fig. 3, 5).

Neoleucopis, subgen. n.

Differs from Leucopis in having a moderately strong pair of praescutellar acrostichals, and a pair of reclinate ocellar bristles.

Genotype, *Neoleucopis pinicola*, sp. n.

Neoleucopis pinicola, sp. n.

Male and Female.—Black, densely gray pruinescent, thorax subopaque, dorsum of abdomen shining on fuscous portions. Head black, frons densely pale gray pruinescent; antennae and palpi black; second segment of former whitish pruinescent. Thorax not vittate. Abdomen with dorsum of basal and second tergites fuscous. Legs black, knees (narrowly) and bases of mid and hind tarsi in male and of all tarsi in female yellowish. Wings hyaline, veins fuscous. Calyptrae and halteres whitish.

Frons a little over one third of the head-width, with very short pale hairs; each orbit about one third the width of interfrontalia; ocelli forming an equilateral triangle; ocellar bristles moderately long; lunule rounded above; third antennal segment not as long as high; genal bristle not surrounded with hairs. Thorax with two or three pairs of weak dorsocentrals, the anterior pairs weakest; about four series of setulae between the dorsocentrals; basal scutellar bristles much shorter than apical pair. Third and fourth wing-veins very slightly convergent apically; penultimate section of fourth vein from one sixth to one fourth as long as ultimate and much shorter than last section of fifth.

Length, 1.25—1.75 mm.

Type and one male paratype, Stratford, Ill., June 22, 1917 (J. R. Malloch). Allotype, Urbana, Ill., May 23, 1885. Paratype, one male, Urbana, Ill., July 31, 1916 (J. R. Malloch).

The author's specimens were all taken on pine trees and the allotype, taken by some collector whose name is not on record, was beaten from pine also. Habits of larva unknown; probably predaceous on aphids on pine.

PLATE XLVI

Thoracic and Cephalic Chaetotaxy of Ochthiphilinae

FIG. 1. *Ochthiphila polystigma*, thorax, dorsal view.
FIG. 2. *Chamaemyia elegans*, same.
FIG. 3. *Pseudodinia polita*, same.
FIG. 4. *Leucopomyia pulvinariae*, same.
FIG. 5. *Ochthiphila polystigma*, head, dorsal view.
FIG. 6. *Chamaemyia elegans*, same.
FIG. 7. *Pseudodinia polita*, head, dorsal view.
FIG. 8. *Neoleucopis pinicola*, same.
FIG. 9. *Ochthiphilia polystigma*, head, lateral view.
FIG. 10. *Chamaemyia elegans*, same.
FIG. 11. *Pseudodinia polita*, same.
FIG. 12. *Leucopis major*, same.

PLATE XLVI

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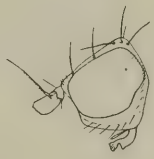

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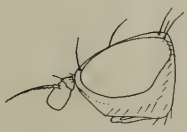

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PLATE XLVII

Wing Venation and Male and Female Genitalia of Ochthiphilinae

FIG. 1. *Leucopis major*, wing.

FIG. 2. *L. piniperda*, male hypopygium, lateral view.

FIG. 3. *Leucopomyia pulvinariae*, same.

FIG. 4. *Leucopis major*, same.

FIG. 5. *Leucopomyia pulvinariae*, male hypopygium, caudal view.

FIG. 6. *Leucopis major*, female genitalia, lateral view.

FIG. 7. *Leucopis pemphigae*, hypopygium of male, lateral view.

FIG. 8. *Leucopis major*, same, caudal view.

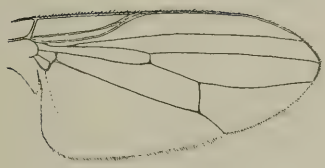
FIG. 9. *L. simplex*, same, ventral view, one side.

FIG. 10. *L. major*, same.

FIG. 11. *L. pemphigae*, same, dorsocaudal view, one side.

FIG. 12. *L. pemphigae*, same, ventral view.

PLATE XLVII



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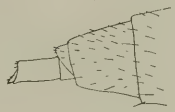

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ARTICLE XV.—*The Small Bottom and Shore Fauna of the Middle and Lower Illinois River and its Connecting Lakes, Chillicothe to Grafton: its Valuation; its Sources of Food Supply; and its Relation to the Fishery.* BY ROBERT E. RICHARDSON.

INTRODUCTION

The present paper, so far as it relates particularly to the valuation of the bottom and shore animals, brings together the results of three summer-autumn seasons of dredging operations in the Illinois River and its connecting backwaters, July, 1913, to October, 1915. The work in the river proper and in the wide expansion of its waters known as Peoria Lake included forty cross-sections at intervals ranging from one to about eleven miles, covering the lower one hundred and eighty miles of the river, or about 80 per cent. of the total distance between the mouth and the head of navigation at La Salle; and embraced a total of three hundred and eighty-seven dredge and dipper collections. The dredging operations in the more inclosed bottom-land lakes were mainly confined to those in the middle Illinois valley district of about fifty-nine miles river length between the Copperas Creek and Lagrange dams, in the lakes and other backwaters of which region three hundred and eighty-five dredge and dipper hauls were taken during the three working seasons.

In addition to the collections of the bottom animals for the valuation studies, sieved samples of the mud deposits on the floor of both the river and the lakes were taken in 1913 and 1914 and analyzed for such indications as they might contain of reasons for differences in productivity of different bottom areas. Between March, 1914, and February, 1915, also, standard sanitary chemical analyses of water samples from a limited number of stations in the upper, middle, and lower river were carried on continuously at weekly intervals with a view particularly to obtaining data on the nitrogen load of the waters and on the rate of progress of its nitrification. Such comparisons as are undertaken with plankton production are with reference mainly to data collected in 1909 and 1910, the most recent seasons devoted at all extensively to plankton operations in the region of the river covered by the present paper. Some principal conclusions from the plankton work of these two years in the river and lakes at Havana, as also from the sanitary chemical analyses of 1914-1915, have already been reported upon in papers by Prof. Forbes and the present writer (Forbes and Richardson, 1913; 1919).

Apparatus.—The collection of the bottom fauna was begun in the summer of 1913 with our ordinary iron dredges (modified "Blake" or

"Naturalist's" type (see pages 367, 368), supplemented in some situations where there was unusually soft mud and where the heavier framed iron dredges were inclined to sink too deeply and fill too quickly, with a lighter framed dredge following closely a recent design by Ekman which was intended for quite a different purpose. (See Fig. 3 and 4.)

Although there was no expectation early in the work of making more than a very rough quantitative application of the biological data obtained, all the dredge hauls were, from the first, of a previously determined and recorded length. The introduction into use in the summer of 1914, for work in water under eighteen feet in depth, of the "mud-dipper" (see Fig. 5), an instrument bearing some resemblance to the Walker dipper-dredge as used by Baker (1916, 1918), and the adoption of finer meshed inner bags for it and the dredges, was the means of what appeared to be rather more accurate work that year than in the first season, while at the same time its use in parallel test hauls of different lengths alongside the iron dredges suggested that averaged results from measured drags, under certain limits of length, with either, had a greater quantitative value than we had at first believed. It was found, in brief, that with a 22″ × 6″ front iron dredge we took on the average as many bottom animals by hauling five feet as by hauling ten, and with a 6-inch mud-dipper as many in two feet as in four, but that in hauls under two or five feet, in either case, we got less. As the average 5-foot haul with the dredge was in the neighborhood of ten times the 2-foot drag of the dipper, and the 2-foot dipper haul about five times a quick deep dip of the mud-dipper to a depth of about three inches (approximate area covered, 25 square inches), it was an easy step to the conclusion that on a rough average, if a few apparently aberrant cases be excluded, the most of the 5- to 10-foot dredge hauls might be safely taken to represent an effective drag of about one square yard, and the 2- to 4-foot hauls of the dipper an effective drag of about 0.1 square yard (125 to 130 square inches). Still more recent parallel tests of the dipper alongside a new Petersen self-closing bottom sampler have not served materially to change these conclusions.

The method used for collecting the small weed animals in the zones of densest vegetation (usually in water under four feet deep) was incomplete, taking in only the small fauna within the 0 to 9-inch depth line. A large bucket of known depth and diameter was lowered about the tops of the plants, the stems were cut off underneath, and then the bucket was brought into an upright position quickly; after which the weed-tops were shaken out in the water saved, and that was finally passed through a 120-mesh sieve. Pulling up the weeds entire in water over two and a half feet deep had shown that the attached weed animals, whether snails, insect larvae, or Crustacea, were, in bulk at least, decidedly most abundant nearer the top. And the adoption of the method also followed, by necessity, some unsatisfactory experience in the use of a small 3-legged caisson and pump—which involved the handling of vastly more material

than was practicable, with also an annoying tendency to in-leakage of outside water at the bottom.

Valuation.—The determination to undertake a valuation of the bottom invertebrate populations that come within the feeding horizon of our ordinary bottom-feeding fishes in terms of pounds per acre was made some time after the conclusion of our field work in 1915, and has been carried out on a basis of estimated average-sized specimens of the various species as they ran in a relatively small number of typical midsummer collections weighed after more than a year's preservation in alcohol and formalin. An average correction of 25 per cent. for loss in weight in alcohol (on a base of *body weight only* for Mollusca, and on a base of *gross weight* for other groups) has been made, after a limited number of experimental weights, in the preserved and the fresh state, of a few snails and insect larvae. The final valuation figures, so far as they include insects, their larvae or other immature forms, worms, or Crustacea, represent gross rough weights, but in the case of the Mollusca (Gastropoda, Sphaeriidae, or young Unionidae) represent the body weight only, after deduction of shell weights at rates determined separately for each species by actual weighing. Sponges, Bryozoa, and other smaller incrusting invertebrates are not included in the valuation figures; as are not also crayfish or pearl-button mussels, except the young.

Acknowledgments.—For many of the hydrographical and physical data we are indebted to the U. S. Army Engineers' survey of 1902—1905 (House Document 263, 59th Congress, 1st session, and accompanying charts); as well as to Alvord and Burdick's recent excellent report (1915) on the Illinois River and its bottom-lands; and, in a lesser degree, to the Report of the Legislative Committee on submerged and shorelands (1911). Thanks are also due Dr. Edward Bartow, Chief of the State Water Survey, for his interested cooperation in obtaining the sanitary chemical analyses of river waters in 1914; and to Prof. S. W. Parr for supervising the analysis of the bottom mud samples taken that year and the year preceding. To Mr. Charles A. Hart is owing a special debt for his assistance in the determination of much of the more unfamiliar biological material of the earlier collections, taken in the preliminary field work of July–September, 1913. Mr. F. C. Baker has contributed both facts and opinions that have made possible rough valuations, for comparison with our own, of the littoral bottom fauna areas of the lower south bay of Oneida Lake, New York, reported upon by him in two very interesting and valuable papers in 1916 and 1918. To these two papers and to Dr. C. G. Joh. Petersen's several recent contributions on the valuation of sea-bottom off the Danish coast (Reports of Danish Biological Station, 1911-1918), I owe not a few ideas which have cast illumination in more or less dark places. The general plan into which the present piece of work is intended to fit, the directing force behind it, and the supply of means and general suggestions as to methods for its execution, have been the work and care for many years of the Chief of the Natural

History Survey, Professor Forbes, without whose aid in these more profoundly important respects the present investigation would doubtless neither have been conceived or carried out in its present scope and form.

Illustrations of Apparatus.—Fig. 1. Iron dredge, showing canvas protector covering posterior bobinet bag, and forward coarse-mesh bag hung backward inside.

Fig. 2. Iron dredge, showing canvas protector rolled back to uncover bobinet bag, and forward coarse-mesh bag pulled out in front of frame.

Fig. 3. Ekman dredge, showing canvas protector covering posterior bobinet bag, and forward coarse-mesh bag hung backward inside; front mud shoes of Ekman design omitted.

Fig. 4. Ekman dredge, disposed as iron dredge in Figure 2.

Fig. 5. Mud-dipper, showing bobinet bag pulled out in front of thimble, and canvas protector in position for drag.

Fig. 6. Apparatus used in 1914 for collecting samples of the thin bottom ooze for study of the composition of the lighter detritus and the microorganisms entering into the food supply of the small bottom animals.

General Summary

It is the purpose of the studies here reported to make an estimate, based on many quantitative collections, of the total store of animal life on and in the bottom sediments of different sections of the middle and lower Illinois River and its bottom-land lakes and on the plants of their shallower, marginal waters, to trace the causes of the wide differences in this respect between river and lakes and between different sections of the stream, to estimate, also quantitativly, the food resources which the bottom muds contain for the animals inhabitating them, and thus to trace in a general way the successive steps by which the organic materials in the muds and waters of the river system are converted into forms available as food for man. This is, in fact, to be regarded as essentially a *soil survey* of these aquatic public properties, for the beds and weedy margins of rivers and lakes are a natural soil of various fertility, of which the animals, mainly univalve mollusks and a few kinds of insect larvae, are the crop, harvested chiefly by fishes, these being harvested in turn by man. From this point of view the *upper* Illinois River is, under present conditions, mainly a mass of plant and animal weeds—forms which occupy the polluted waters to the practical exclusion of everything useful to human kind—but the current of this section carries elements of a normal fertility to the lower reaches of the river, depositing a large part of them finally in the silts and sediments of river and lake in forms available for the nutrition of normal aquatic life, but bearing also an immense quantity to the mouth of the stream where it escapes unutilized into the Mississippi.

The river system below Chillicothe varies enormously in the productiveness of its different parts, the richest of them being the weedy margins

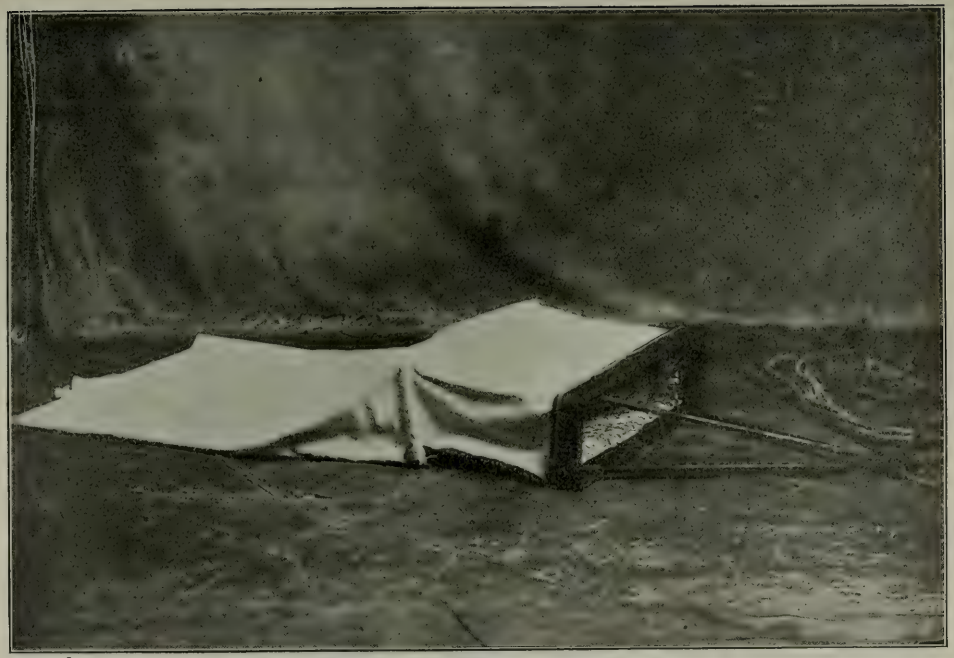

FIG. 1. Iron dredge, showing canvas protector covering posterior bobinet bag, and forward coarse-mesh bag hung backward inside.

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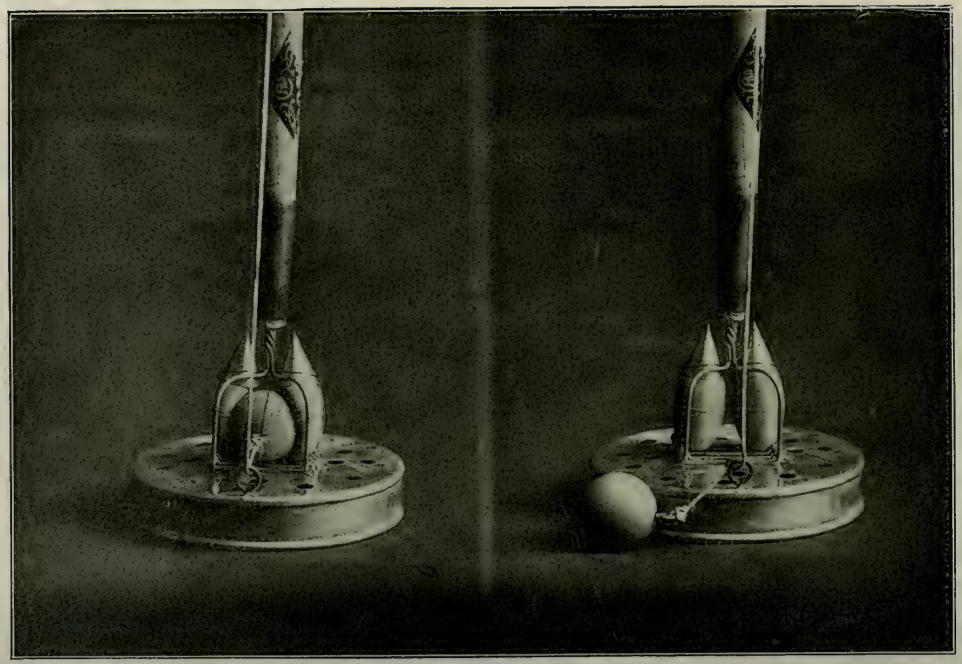

FIG. 6. Apparatus used in 1914 for collecting samples of the thin bottom-ooze for study of the composition of the lighter detritus and the microorganisms entering into the food supply of the small bottom-animals.

of the shallower lakes, and the poorest those sections of the river channel which are swept comparatively bare of sediments by a relatively swift flow. In the river itself much the most abundant product is found where the current is most sluggish, and the bottom sediments are consequently deepest and are most heavily charged with organic materials originally washed into the stream by rains or poured into it by sewers of cities and towns and transformed by oxidation into compounds suitable for the nutrition of clean-water plants and animals.

In a stretch of the river above Havana, which, with its adjacent lakes, is the richest part of the Illinois River system, the inshore and bottom fauna of the lakes averages in weight to the acre about twice as much as that of the river, and it is in the lakes that the fisheries give their highest yield. The bottom soils of the lakes are, indeed, richer in organic matter, as a rule, than are those of the river opposite, and the muds of the marginal waters of these lakes are richer than those of their deeper parts—facts traceable, in part, no doubt, to the more abundant light and higher temperature of the shallower waters and the consequent greater growth of plants whose decay enriches the soil from which they sprang.

At ordinary high-water levels the current of the river from Chillicothe to the mouth varies from one to two miles per hour according to the slope of the bottom, the width of the bed, and the presence or absence of obstructions; and at the highest water it does not much exceed three miles per hour for any important distance. At ordinary midsummer levels the current rate per hour varies in different sections from half a mile to a mile. At lowest water it drops, between Chillicothe and the foot of Peoria Lake, to as little as .29 mile per hour.

Above Havana the bottom, both along the shores and in the channel, is, with some exceptions, a rather deep black mud, but below Havana this shades gradually into hard clay or sand and shells, soft mud failing completely in the channel for long distances. The quantity of inshore vegetation is negligible in the river proper, even in the driest seasons, since the opening of the sanitary canal of the Sanitary District of Chicago in 1900. The bottom-land lakes between Copperas Creek and Lagrange are gradually filling with river silt and a growth of plants. A few have sandy beaches next the eastern bluffs, but the bottoms of all are otherwise of deep black mud, mixed in the shallow water along shore with coarse rotting vegetation. In midsummer the margins of all the deeper lakes, to a depth of four to six feet, are well supplied with vegetation, while the shallower lakes are in many cases weedy over their entire acreage.

From Chillicothe to Lagrange the animal life of both channel and shore waters is almost wholly mollusks (86 to 99 per cent. in collections made), but below Lagrange insect larvae (caddis-worms and May-fly larvae) were more abundant than above in the shore muds, the ratio of mollusks falling to 31 to 65 per cent. In the deeper, opener lakes, mollusks made 77 to 96 per cent. of the collections, and in the shallower, more weedy lakes, 36 to 79 per cent.

Speaking generally, the richest sections of the river floor are those with the least average slope and the slowest current, and therefore with the most abundant sediments. The quantity of the bottom fauna diminishes rapidly down-stream from Chillicothe, averaging 555 pounds to the acre for the upper sixty miles (the weight of the shells of the mollusks being in all cases deducted), 88 pounds for the forty-two and a half miles next following, and 10.4 pounds for the lower seventy-seven miles. The general average for the river channel from Chillicothe to the mouth was 261 pounds per acre. That for Copperas Creek to Lagrange, within which section lay the twelve principal lakes studied, was 705 pounds per acre, and the highest sectional yield was 2,693 pounds per acre between Copperas Creek and Havana. The highest local yield was found in the lower half of this Copperas Creek-Havana section, whose channel product rose to 5,196 pounds per acre. These enormous yields in the stretch above Havana were evidently due, at least in great measure, to the sluggish current and consequent heavy sedimentation and to the great predominance (99 per cent.) of relatively large, thick-shelled snails, edible only by the larger fishes, armed with a powerful crushing apparatus in jaws and throat.

In the muddy section of river above Havana the channel yields approximated or even surpassed those of the shallow waters along shore; but below Havana, where mud is largely replaced by sand, clay, or shells, the channel yields were only 5 to 10 per cent. those of the longshore zone.

Comparing river and lakes between Copperas Creek and Lagrange (59.3 miles) we find that the average bottom yield per acre of twelve lakes examined was about one third that of the river opposite them, but that it was practically the same as the average for the entire river from Chillicothe to the mouth. The deeper lakes with sandy beaches at one side yielded about twice as much per acre as the shallower lakes with mud banks all around.

In the deeper bottom-land lakes surrounded by mud banks, the shore belt, to a depth not exceeding six feet, yielded about three times as much bottom fauna per acre as the deeper open water of these lakes; but in the sand-beach lakes this relation was reversed, the deeper bottom yielding five or six times as much as that within the 6-foot line.

The foregoing statements all apply to the animals living in or on the bottom muds; but in the shallow, *weedy areas* of lakes and backwaters the small invertebrate animals living on and among the weeds greatly exceed both in number and in weight per acre the fauna of the bottom itself, aggregating in many collections made near Havana in 1914, from 1,100, to nearly 2,600 pounds per acre, with an average of 2,118 pounds—quantities to be compared with an average of 255 pounds of *bottom fauna* per acre from the lakes of the same district.

Combining weed and bottom faunas of our collections and applying their joint averages to the entire area of lake and backwater between

Copperas Creek and Havana, we get a yield of 1,447 pounds per acre, to be compared with 705 pounds per acre for the unusually rich sections of the river opposite.

From analyses of the bottom muds of the river channel and estimates of the nitrogen content of total bottom fauna per acre, it appears that the nitrogen in the river sediments is many hundred times the nitrogen content of the flesh of the animals living in them, and that the total dry organic matter in the channel muds is several thousand times the dry weight of this bottom fauna.

Chemical analyses show that the bottom soils of the lakes are richer in organic matter than those of the river opposite them, and that in the lakes themselves the bottom soil is richer near the shore than at the center.

The plankton of the river passing Havana in a year amounts to about 200,000 tons live weight, equivalent to four thousand to ten thousand tons dry weight. This is, roughly, 20 to 50 times the total dry weight of the flesh of the animals of the bottom muds of the lakes from Copperas Creek to the mouth, a distance of 138 miles.

An estimated total of 600,000 tons dry weight of organic matter, suspended and dissolved, passed Chillicothe in 1914. This is 60 to 150 times the dry weight of the plankton that passed Havana in twelve months (1909 and '10), and 3,000 times the dry weight of the total bottom fauna of 1915 from Copperas Creek to the mouth of the river. The dry weight of nitrogen in the above organic matter was sufficient to replace the nitrogen in the plankton of a year from 92 to 232 times.

The plankton per cubic meter of water was greater throughout the year in Thompson Lake than in the river opposite in 1909 and '10, the difference being greatest at times of lowest production (midsummer and winter) in both river and lake.

The river plankton is constantly settling to the bottom to an important degree, as is shown by the composition of the bottom ooze and by the stomach contents of small invertebrates living on and in it. In June, 1914, living, moribund, or recently dead limnetic plankton was more abundant in the upper layers of the ooze than the normal bottom plankton or old organic detritus, as was shown by the food of Sphaeriidae, Trichoptera, and Chironomidae, and it made also an important part of the food of large detritus-eating gastropods (Viviparidae, Pleuroceridae, etc.).

There is a much greater loss of plankton down-stream than can be explained by dilution merely. The falling off in plankton per cubic meter between Havana and Grafton amounted, during nine months of the growing season, to approximately 62 per cent., notwithstanding the normal rate of multiplication of the planktonts as they passed down stream. These losses were greatest when the current was slowest and settling consequently easiest. They were not due to lack of food, because the percentage of nitrogen and the nitrates increased from Havana downward.

In our opinion and that of the most intelligent and observant fishermen, the lakes are the favorite feeding grounds of the larger and more common fishes, and this opinion is supported by the fact that the lakes have a more abundant food supply per acre than the river, and that the heaviest fish-yields come from sections where the ratio of lake areas to river is greatest.

The average weights of the yields of the inshore bottoms of the Illinois River lakes in 1915 were about five times as great per acre as those of the glacial lakes of northeastern Illinois in 1916, and the composition of the faunas was also widely different, mollusks occurring in the latter in relatively insignificant proportion and being nearly all of the smaller species. The weed faunas of Fox and Pistakee lakes were almost wholly made up of small crustaceans and insects, the former predominating, although the total weights were not very much less than those of the Illinois system.

Hydrography and Bottom Fauna, Illinois River, Chillicothe to Grafton, July–October, 1915

(a) Chillicothe to Foot of Peoria Lake (18.5 Miles)

Hydrography.—If the Illinois River is a sluggish stream considered as a whole, in comparison with most other important American rivers, the grand prize for local leisureliness of movement belongs to the short stretch between Chillicothe and the lower end of Peoria Lake, where, in March, 1903, *at a flood stage* of approximately eighteen feet above old low-water marks at Peoria, it took ball floats twenty-nine hours and fifty-nine minutes to make a total distance of 17.7 miles, the average rate per minute being 51.94 feet, and per hour, 0.59 mile. At a gage of nine feet, Peoria, which is almost exactly the mean level of the month of August, 1914, and represents the lowest water in this part of the river in the past seven years, these rates would be reduced to 25.97 feet per minute or 0.29 mile per hour—a total time in transit of fifty-nine hours and fifty-eight minutes for the 17.7 miles.

These velocities compare with an average of 229.47 feet per minute or 2.60 miles per hour at a corresponding flood gage for the 33.9 miles Morris—Utica; and with 115.43 feet per minute or 1.31 miles per hour for the 229.6 miles between Utica and Grafton. Above Peoria only the 12-mile section Henry—Hennepin has a current approaching the low figures found between Chillicothe and Peoria. In the other short reaches above Peoria, and in all below Peoria except the section of 8 miles between Liverpool and Havana (with 66.00 feet per minute, or 0.75 mile per hour), average flood velocities are over 100 feet per minute (1 mile per hour). The greatest velocities below Utica occur in the 9.8 miles between Peoria and Pekin (with 191.64 feet per minute or 2.17 miles per hour); and in the reaches below Florence, which have over 180 feet per minute, or more than 2 miles per hour.

TABLE OF APPROXIMATE AVERAGE VELOCITIES, ILLINOIS RIVER

This table is based on float records of J. L. Van Ornum, as published in Water Supply Paper No. 194, U. S. Geological Survey, 1907, pp. 17-18.

(The gage at Peoria averaged about eighteen feet during the tests. The figures for nine feet are one half the 18-foot figures, various measurements by the U. S. Geological Survey and others showing about 50 per cent. decrease in velocity between approximately these gages at Peoria and corresponding gages at other stations.)

Reach	Miles	Gage, 18 ft., Peoria		Gage, 9 ft., Peoria	
		Ft. per min.	Mi. per hour	Ft. per min.	Mi. per hour
Morris to Utica	33.9	229.47	2.60	114.73	1.30
Utica to Grafton	229.6	115.43	1.31	57.61	0.65
Utica to Hennepin	21.6	137.73	1.56	68.86	0.78
Hennepin to Henry	12.0	67.33	0.76	33.66	0.38
Henry to Chillicothe	15.5	103.98	1.18	51.99	0.59
Chillicothe to foot Main St., Peoria	17.7	51.94	0.59	25.97	0.29
Foot Main St., Peoria, to Pekin	9.8	191.64	2.17	95.82	1.08
Pekin to Banner*	14.3	114.40	1.30	57.20	0.65
Banner to Liverpool	10.7	105.01	1.19	52.50	0.59
Liverpool to Havana	8.0	66.00	0.75	33.00	0.37
Havana to Beardstown	31.5	129.13	1.46	64.56	0.73
Beardstown to Lagrange dam	11.0	152.04	1.72	76.02	0.86
Lagrange to Florence	21.9	146.92	1.66	73.47	0.83
Florence to Kampsville dam	24.2	183.85	2.08	91.92	1.04
Kampsville dam to Grafton	31.4	186.91	2.12	93.45	1.06

Differences in velocity within the 18 miles between Chillicothe and Peoria are indirectly shown in the next table in figures for elevation of water surface at the low gage of 1901. In more than thirteen out of the eighteen miles the decline was too small to be measured; for one-half mile there was an average slope of over two inches; and in the lower four and a half miles a slope of about three fourths of an inch per mile.

Widths between banks in this section of the river at the low water of 1901 ranged from 439 feet just below Chillicothe to more than a mile in the widest parts of the expanded portion known as Peoria Lake, which occupies more than seventeen of the eighteen and a half miles. If we figure the normal area of the river proper per mile throughout the reach at the 1901 low water at a mean (80.0 acres per mile) between the

* About 2 miles above Copperas Creek dam.

DECLINE IN ELEVATION OF LOW-WATER SURFACE, 1901

Reach	Interval miles	Av. slope (inches) per mile
Chillicothe—foot Peoria Lake	18.3	0.26
Chillicothe (mile 180.5)—Mile 171.0*	9.5	Not measurable
Mile 171.0—170.5	0.5	2.40
Mile 170.5—166.9	3.6	Not measurable
Mile 166.9—165.5	1.4	0.85
Mile 165.5—163.8	1.7	0.70
Mile 163.8—162.2 (foot of lake)	1.6	0.75

averages just above and just below Peoria Lake, this is found to be less than one fourth of the actual average continuous area flooded in each mile (379.9 acres); or, in other words, the river was on the average throughout this eighteen-mile section at those levels more than four times normal width. The ex-river or lake acreage per mile at the low water of 1901 figured in this way (379.9—80.0=299.9 acres per mile) in fact exceeded that found for any other sections of the river except two, viz., the 16.8 miles between Copperas Creek dam and Havana and the 42.5 miles between Havana and the Lagrange dam.

LAKE AND POND ACREAGE, LOW WATER, 1901
(AS IN VALLEY BEFORE LEVEES)

Reach	Interval miles	Lake and pond acreage per mile
Chillicothe to foot Peoria Lake	18.5	299.9
Foot Peoria Lake to Pekin	9.0	113.6
Pekin to Copperas Creek dam	16.2	219.0
Copperas Creek dam to Havana	16.8	472.1
Havana to Lagrange dam	42.5	382.4
Lagrange dam to Florence	21.9	219.6
Florence to Kampsville dam	24.2	180.0
Kampsville dam to Grafton	31.4	86.9

Depths in the river channel between Chillicothe and the foot of Chillicothe Island (0.9 mile below Chillicothe, the point where the expansion into the wide waters of Peoria Lake begins) were 22.5 to 24 feet at the low water of 1901, and have been about four and a half feet more than those figures at recent low gages. The channel through the lake at the low water of 1901 varied in depth from about seven to a little over twenty feet; and at recent low levels from over eleven to over twenty-four feet.

* Mile figures represent miles above Grafton.

WIDTHS AND DEPTHS, CHILLICOTHE TO FOOT OF PEORIA LAKE, LOW WATER, 1901

Miles above Grafton	Station	Width, ft.	Depth, ft. max.
	Unwidened river—		
180.2	500 yds. below boat-landing, Chillicothe	494	24.0
179.6	Foot Chillicothe Island	439	22.5
	Upper lake—		
178.4	Head Peoria Lake, one half mile above Rome	1,000	17.0
177.9	Rome	3,960	14.0
175.5	One and a half miles above Spring Bay	5,463	7.5
	Middle lake—		
173.4	500 yds. below Spring Bay	1,024	10.8
173.1	About half a mile below Spring Bay	1,850	16.8
169.5	Three miles above Peoria Narrows	5,627	10.0
168.0	One and a half miles above Peoria Narrows	5,280	20.1
	Lower lake—		
166.5	Peoria Narrows (above bridge)	658	15.5
164.2	Opposite work-house	3,922	12.5
162.5	Opposite foot Main St.	1,760	10.8
162.2	Lower wagon-bridge	870	5.1

As we should expect, the upper soil strata in the channel throughout most of this section consist of dark-colored mud of a good depth. The mud layer is four feet deep in the channel at Chillicothe, and ranges from 7.5 to over 22 feet in depth at boring stations (U. S. Engineers, 1902–05) in the upper, middle, and lower lakes, if we except a stretch of less than two miles in and immediately below Peoria Narrows. At the Narrows and just below, cap-rock comes to within four or five feet of the surface, and the upper stratum consists of a well-packed mixture of mud and shells. This is followed for about a mile by a deep upper layer of dirty sand and shells, after which (between Mile 165 and Mile 164) deep mud begins again and is continued to the foot of the lake. At the foot of the lake rock comes again to within eight feet of the surface, and the floor of the river just above the mouth of Farm Creek is formed by gravel fifteen feet deep—hard bottom of sand or sand and shells continuing from this point all the way to Pekin.

Findings regarding bottom deposits at our collecting stations in 1915 agree very well, as far as they go, with the data from the government borings, and are satisfactorily consistent with such data as we have on slope and velocity. The mud brought up by the dredges, except at Peoria Narrows, was all very dark in color, and the recent origin of much of it was indicated by the softness of the upper layers. Measurements

of the "depth to hard bottom"* ran from thirty-six to seventy-two inches at stations between Rome and the foot of Main St., Peoria. At the Narrows the mud was harder, lighter in color, and was mixed with old dead shells and thickly carpeted with sponges and Bryozoa.

Depth (of Softer Mud) to Hard Bottom at Channel Stations

Miles above Grafton	Station	Inches
180.5	Chillicothe	3
177.2	One mile below Rome	72
175.5	Peoria Narrows	Hard bottom
172.3	Opposite Mossville	48
166.5	One and a half miles above Spring Bay	36
162.7	Opposite foot Main St.	36

The elevation of the bottom of the river channel eighteen miles south of Chillicothe, instead of being lower, is actually more than eighteen feet higher than the plane of greatest depth opposite Chillicothe; more than fourteen feet above the bottom plane of the deepest part of Peoria Lake above the Narrows; and more than two feet *higher* than the *highest* point in the channel bottom between Chillicothe and the foot of the lake. I think we must suppose that the way out of Peoria Lake was once much more open, and that the action of Farm Creek has been largely responsible for building up the high bar that now dams up the entrance into the Pekin reach. The nearness to the surface of rock between Peoria Narrows and Wesley would, however, have prevented in any case the excavation of a fast and deep channel through the Chillicothe-Peoria section.

Because of the very shallow gradient, and the great expansion of the river between Chillicothe and Peoria, the shallower backwater in most of the distance, though not separable from the river channel by any distinct boundary, resembles more nearly the larger inclosed bottomland lakes than ordinary river littoral. Except for a very short distance at and near Peoria Narrows, the land to the eastward of the channel is low, the banks are all of mud, and the soft bottom sediments very dark in color. Within the 3-foot line on this side the bottom muds contain more decayed vegetable matter than further out, and there is a good deal of living vegetation (principally Potamogetons and Ceratophyllum) during the dry season. On the west side of the channel, sand or gravel or hard mud bottom is found for considerable distances out to a depth of three to seven feet wherever the channel closely approaches the bluff. Opposite Mossville, where the channel is east of the middle of the lake, the 1–3- and 4–7-foot zones on the west side are very similar in midsummer to those on the east side first described. Except for a short dis-

* Made by forcing a 2 × 2-inch pole, square across the end, as deeply into the mud as a strong man could with both hands.

tance at this place, such vegetation as grows on the west side is usually only a thin fringe next the rather steep bank. Outside the 4-foot line Peoria Lake has recently been almost entirely free of vegetation, even at the lowest gages, and it is consequently much more subject to roiling by winds than the narrower and weedier lakes near Havana.

The Bottom Fauna.—Collections of the small bottom animals, with dredges and mud-dipper, were made in the channel July 26 to August 19, 1915, at four stations in the mud-section between Chillicothe and Peoria Narrows; in the hard mud at Peoria Narrows; and in the mud opposite the steamboat landing at Peoria.

CHANNEL COLLECTIONS, CHILLICOTHE TO PEORIA LAKE, 1915

Miles above Grafton	Station	No. collections July—August, 1915	Depth adjusted to gage July—October, 1910—1914	
180.5	Chillicothe	2	28	Deep, narrow river
177.2	One mile below Rome	1	12	
175.5	One and a half miles above Spring Bay	3	11	Upper lake, channel
172.3	Opposite Mossville	2	19	Middle lake, channel
166.5	Peoria Narrows	3	19	
162.7	Opposite Eagle Packet landing	4	15	Lower lake, channel

Total channel collections..... 15

The average number of bottom animals in a square yard of channel bottom, if we except the Peoria Narrows station (which represents a very limited area with hard bottom), compared favorably (at 235 per sq. yd.) with the figures from some other short reaches between Peoria and Havana, but was under the average for the 60.5 miles (416 per sq. yd.), and was far below the figure for the very rich section of eight miles just above Havana (1,469 per sq. yd.). In all the collections Mollusca (Gastropoda and Sphaeriidae) were much more numerous than insects, worms, and small Crustacea; and the larger Gastropoda (Viviparidae and Pleuroceridae) were usually more abundant than the Sphaeriidae and smaller Gastropoda (Amnicolidae, etc.).

BOTTOM FAUNA, CHANNEL, 1915
NUMBERS PER SQUARE YARD, AVERAGE

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total	Collections
Chillicothe—Mossville	88.2	143.7	26.6	258.5	8
At Peoria Narrows	23.2	1.0	13.3	37.5	3
Peoria Narrows to foot of Peoria Lake	134.5	5.0	48.0	187.5	4
Average (excepting collections at Narrows)				234.8	12

The average valuation of the channel bottom fauna in pounds per acre (shells of Mollusca deducted) in this section (285.9 pounds, with the Peoria Narrows station included; 345.1 pounds, with Peoria Narrows omitted) was better than the average (239 pounds) for the 43.7 miles between Chillicothe and the Copperas Creek dam, but was less than one tenth of the channel average between Copperas Creek dam and Havana (3,029 pounds per acre), and less than one twentieth of the average valuation for the eight miles between Liverpool and Havana in 1915 (5,180 pounds per acre). The great bulk of the collections, by weight (85 per cent.), was made up of the larger snails (Viviparidae and Pleuroceridae), and these families together with the Sphaeriidae and smaller Gastropoda accounted for about 98 per cent. of the average poundage taken.

BOTTOM FAUNA, CHANNEL, 1915
POUNDS PER ACRE, AVERAGE

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total	Collections
Chillicothe to Mossville	244.1	70.4	3.1	317.6	8
At Peoria Narrows	46.3	0.5	2.1	48.9	3
Peoria Narrows to foot of Peoria Lake	391.6	3.1	5.6	400.3	4
Average (including Narrows)	243.8	38.4	3.5	285.9	15
Per cent. of total	85.2	13.4	1.4		
Average (excluding Narrows)	293.2	47.8	3.9	345.1	12
Per cent. of total	84.9	14.0	1.1		

A total of thirty collections in the shallower areas between Chillicothe and the foot of Peoria Lake were taken with the mud-dipper in 1915; ten within the 4-foot line, and twenty between the 4- and 7-foot lines (depths adjusted to gage July–October, 1910–1914).

SHORE COLLECTIONS, CHILLICOTHE TO FOOT OF PEORIA LAKE, 1915

Miles above Grafton	Station	1- to 3-foot zone	4- to 7-foot zone
		Collections	Collections
180.5	Chillicothe	...	2
177.2	One mile below Rome	3	5
175.5	One and a half miles above Spring Bay	2	5
172.3	Opposite Mossville	4	4
162.7	Opposite Eagle Packet Landing	1	4
Total collections		10	20

Average numbers per square yard in the 1- to 3-foot zone (233.7) were about the same as in the channel opposite (234.8), but were appreciably under those found in the 4- to 7-foot zone (314.6). Both in the 1- to 3-foot and the 4- to 7-foot zones there were proportionally much larger numbers of Sphaeriidae and of insects, worms, and small Crustacea than were present in corresponding channel collections.

BOTTOM FAUNA

1- TO 3-FOOT ZONE, 1915

NUMBERS PER SQUARE YARD, AVERAGE

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total	Collections
Chillicothe to Mossville	7.7	148.6	76.3	232.6	9
Peoria Narrows to foot of Peoria Lake	50.0	70.0	120.0	240.0	1
Average	....	....	....	236.3	10

The average *poundage* per acre of bottom animals in the 1- to 3-foot zone* (108.4 pounds) was less than one third the average channel valua-

* No collections at Peoria Narrows.

4- to 7-foot Zone, 1915

NUMBERS PER SQUARE YARD, AVERAGE

Chillicothe to Mossville	30.8	200.3	68.7	299.8	16
Peoria Narrows to foot of Peoria Lake	53.0	167.5	52.5	373.5	4
Average	....	....	....	314.4	20

tion opposite (345.1 pounds), although *numbers* per unit area were about the same, the Sphaeriidae and smaller Gastropoda making up over 50 per cent. of the average in weight and the insect larvae, worms, and Crustacea over 7 per cent. as compared with much smaller ratios in the channel collections.

The average 4- to 7-foot zone* valuation (259.4 pounds per acre) was about two and a half times that of the 1- to 3-foot zone (108.4 pounds), and about 25 per cent. under the average channel valuation (345.1 pounds). The larger snails (Viviparidae principally), while not relatively so abundant as in the channel collections, made up a noticeably larger portion (64.6 per cent.) of the totals by weight than was the case in the 1- to 3-foot zone.

Tables summarizing these comparisons of the channel and shore zone averages follow. Further details concerning separate species and families included in the valuations are found in the detailed tables at end.

Bottom Fauna, Chillicothe to Foot of Peoria Lake,* 1915

Summary

	Channel, 12 collections	4- to 7-foot zone, 20 collections	1- to 3-foot zone, 10 collections
Average number per square yard	234.8	314.6	233.7
Average pounds per acre	345.1	259.4	108.4
Per cent. (by weight) Viviparidae and Pleuroceridae	84.9	64.6	41.3
Per cent. (by weight) Sphaeriidae and small Gastropoda	14.0	30.9	51.6
Per cent. (by weight) Insects, worms, Crustacea	1.1	4.5	7.1

* No collections at Peoria Narrows.

* Channel collections at Peoria Narrows omitted. No collections taken in 1- to 3-foot or 4- to 7-foot zone at that station.

BOTTOM FAUNA

1- TO 3-FOOT ZONE, 1915

POUNDS PER ACRE

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total	Collections	Channel total for comparison	Collections
Chillicothe to Mossville	30.1	61.2	7.9	99.2	9	317.6	8
Peoria Narrows to foot of Peoria Lake	174.0	9.8	7.4	191.2	1	400.3	4
Average	44.5	56.0	7.8	108.4	10	345.1	12
Per cent. of total	41.3	51.6	7.1				

4- TO 7-FOOT ZONE, 1915

POUNDS PER ACRE

Chillicothe to Mossville	97.4	86.7	13.3	197.4	16	317.6	8
Peoria Narrows to foot of Peoria Lake	446.3	55.5	5.8	507.6	4	400.3	4
Average	167.1	80.4	11.8	259.4	20	345.1	12
Per cent. of total	64.6	30.9	4.5				

(b) Foot of Peoria Lake to Pekin (9 Miles)

Hydrography.—After passing over the high bar above the mouth of Farm Creek (foot of Peoria Lake) the river follows a comparatively swift and narrow channel to Pekin, the average velocity at a flood gage of eighteen feet, Peoria, being 191.64* feet per minute for the 9.8 miles between the foot of Main St. and the wagon bridge at Pekin, and the width (at low water of 1901) usually under six hundred feet. The average slope of the water surface at the low levels of 1901 was two inches per mile, and 4.36 inches per mile at the high water of March, 1904. These average slopes and velocities are much greater than are met with in any other considerable section of channel in the one hundred and twenty-five miles between Chillicothe and Florence, and are four to seven times the figures for the 18.5 miles between Chillicothe and the foot of Peoria Lake.

Decline in Elevation of Water Surface

Reach	Stage of river	Interval miles	Av. slope inches per mile
Foot of Peoria Lake to Pekin	Low water 1901	9.2	2.00
"	Flood stage Mar. 15, 1903	9.2	3.45
"	Flood stage Mar. 31, 1904	9.2	4.36
Chillicothe to foot Peoria Lake	Low water 1901	18.3	0.26
"	Flood stage Mar. 31, 1904	18.3	0.64

The channel floor is sand and shells, nearly denuded of mud, for most of the nine miles. At our 1915 collecting stations between Wesley and Pekin the bottom was hard, but opposite Pekin the hard bottom was overlaid with a very thin covering of soft silt. Between the 4- and 7-foot lines at Wesley in 1915 hard gravel bottom washed clean of mud was found both on the east and west sides. At the shore stations below the wagon bridge at Pekin six inches of soft mud was found on the west side and 12 to 36 inches on the east. Shore vegetation, except an occasional narrow fringe at the bank edge, is wanting.

At the low water of 1901 the bank to bank width of the river between Peoria and Pekin was usually between 400 and 600 feet, only a very short stretch just below the mouth of Farm Creek much exceeding 600. Depths in the wider and shallower stretches ranged from 7 to 8½ feet; and in the deeper and narrower ones between 10 and 13 feet. Average depths at recent low levels (gage of July–October, 1910–1914) have been about 3½ feet more than these figures. The connecting lake

* Table, p. 377.

acreage (113.6 acres per mile at the low water of 1901) is little more than a third of that which occurs between Chillicothe and the foot of Peoria Lake (299.9 acres per mile); and is under the rating of any other section of the river between Chillicothe and Kampsville.*

WIDTHS AND DEPTHS, FOOT OF PEORIA LAKE TO PEKIN, LOW WATER, 1901

Miles above Grafton	Station	Width, ft.	Depth ft. max.
161.9	50 yds. below mouth Farm Cr.	347	8.1
160.7	P. & P. U. R.R. bridge.....	915	6.6
159.9		640	11.8
159.0	100 yds. below Wesley.....	402	8.3
158.0	.....	514	7.5
157.0	.....	586	7.5
156.0	.....	640	7.2
155.0	.....	515	8.5
153.9	.....	439	12.4
153.3	.....	475	10.3
153.0	Pekin, at wagon bridge.....	...	11.2

Bottom Fauna.—The bottom collections made in cross-sections at Wesley and Pekin in 1915 included four channel hauls and four hauls in the 4–7-foot zone. In neither depth zone was a fauna indicated quite so rich as that of the channel and shore zones between Peoria and Chillicothe, the average channel poundage amounting to 253.8 lbs. per acre, and that of the 4–7-foot zones to only 206.3 lbs.

Larvae of caddis-flies (principally Hydropsyche sp.) were decidedly more abundant in the swifter stretches of channel between Peoria and

BOTTOM FAUNA, CHANNEL, WESLEY TO PEKIN, 1915

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Number per sq. yard. Average	87.7	16.7	129.0	233.4 4 collections
Pounds per acre, av.	224.6	8.3	20.9	253.8 4 collections
Per cent. of total, (By weight)	88.6%	3.2%	8.2%	

* See table, p. 378.

Pekin than above Peoria, and the Sphaeriidae less so. The larger Gastropoda (Viviparidae and Pleuroceridae) made up about the same percentage of the average weight of collections as above Peoria (88.6%). In the 4–7-foot zone the Sphaeriidae showed the heaviest poundages (66.2% of totals), and the insect larvae and the larger snails were relatively much less abundant than in channel collections.

Bottom Fauna, 4—7-foot Zone, Wesley to Pekin, 1915, Average

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Number per sq. yard	20.0	272.5	56.5	349.0 4 collections
Pounds per acre	60.0	136.7	9.6	206.3 4 collections
Per cent. of total, (By weight)	29.2%	66.2%	4.6%	

(c) Pekin to Copperas Creek Dam (16.2 Miles)

Hydrography.—Following the swift run from the foot of Peoria Lake to Pekin, where the low-water slope in 1901 was 2.00 inches per mile, the effect of the dam at Copperas Creek became very distinct below Pekin at those low levels, and the average slope of water surface between Pekin and the dam fell to 0.14 inch per mile. Although this average low-water decline is not much more than half that between Chillicothe and the foot of Peoria Lake (0.26 inch per mile for 18.2 miles), at ordinary spring flood-levels the slope rate is multiplied ten times or more (1.40 inches per mile at gage 18 ft., Peoria), and the average flood velocity (114.40 feet per minute at gage 18 ft., Peoria) rises to a figure more than double that between Chillicothe and Peoria.*

This circumstance—a consequence of the fact that at flood stages the sweep of the current tends to follow the old lines of slope of water surface as they existed before the low-crested dam was put in—accounts for the generally well-scoured channel floor that we find throughout this reach of 16.2 miles, not even excepting its lowermost portion just above the dam.

The only important stretch of soft mud bottom in the channel in the 16 miles is the deposit occupying less than a mile of channel length just above the mouth of the Mackinaw. With the exception of that and of about a mile of dirty sand which ends a mile above the dam, the gov-

* Table, p. 377.

DECLINE IN ELEVATION OF WATER SURFACE

Reach	Stage of river	Interval miles	Av. slope inches per mile
Pekin to Copperas Creek dam (above)	Low water 1901	16.2	0.14
Pekin to Copperas Creek dam (above)	Flood stage Mar. 15, 1903	16.2	1.36
Pekin to Copperas Creek dam (above)	Flood stage Mar. 31, 1904	16.2	1.43

ernment borings of 1902–1905 showed hard bottom at all channel stations, the upper layer of sand, gravel, or sand and shells having depths of from five to twenty-nine feet. In the shore zones within the 7-foot line mud bottom was found by us in 1915 at all the collecting stations. There is no shore vegetation worth mentioning in the 16 miles.

Between Pekin and Copperas Creek dam at the 1901 low levels, bank to bank widths averaged rather greater than in the Peoria-Pekin section, being usually over 600 feet, and for short distances 700 feet and over. The greatest depths at these levels were under 15 feet, and in a

WIDTHS AND DEPTHS, PEKIN TO COPPERAS CREEK DAM, LOW WATER, 1901

Miles above Grafton	Station	Width, ft.	Depth, ft. max.
153.0	Pekin at wagon bridge	...	11.2
152.8	.....	695	13.0
152.5	.....	...	7.1
151.7	.....	750	10.2
150.5	.....	440	11.0
149.9	.....	677	8.6
149.3	.....	384	14.1
149.0	.....	600	9.0
147.9	.....	610	12.6
146.8	.....	695	7.4
145.6	Kingston	700	8.7
145.2	.....	549	14.7
144.6	.....	732	7.0
143.9	.....	622	8.4
142.9	.....	586	8.3
141.3	.....	530	11.6
139.0	.....	550	8.4
138.3	.....	586	14.5
137.7	.....	570	9.3
137.2	.....	677	10.4
136.95	.....	549	11.0
136.8	Dam		

large part of the section ranged between 7 and 9 feet. Recent maximum low-water depths have been mostly 2 to 3½ feet more than these. The connecting lake and pond acreage in this section at the low levels of 1901 (219.0 acres per mile) was about twice that between Peoria and Pekin per mile of river length, but was not much more than two thirds that between Chillicothe and the foot of Peoria Lake, and was less than half that between Copperas dam and Havana.*

Bottom Fauna.—A total of 14 channel collections and 16 shore collections were made between Pekin and the dam in 1915 at stations as shown below.

Miles above Grafton	Station	Channel	4—7-ft. zone	1—3-ft. zone
151.5	1½ miles below Pekin	2	2	
145.6	Opposite Kingston	6	3	3
141.9	Opposite Spring Lake canal	4	4	4
136.8	100 yards above dam	2		
	Total	14	9	7

The average valuation figure for the channel fauna in the section (144.8 lbs. per acre) was lower than in any other important stretch of channel between Chillicothe and Havana. The weight of the average channel collection was not far from equally divided between the Sphaeriidae and the larger Gastropoda, the first contributing 43.7%, the

Bottom Fauna, Channel, Pekin to Copperas Creek Dam, 1915

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Number per sq. yard, Average	28.8	126.9	49.8	205.5 14 collections
Pounds per acre, Average	73.3	63.4	8.1	144.8 14 collections
Per cent. of total, (By weight)	50.6%	43.7%	5.7%	

* Table, p. 378.

latter 50.6%. The insects, worms, and small Crustacea made up the remaining 5.7%, the greater part of which was composed of the larvae of the commoner channel caddis-flies.

In the shore zones both numbers and weight valuations were conspicuously higher than in the channel, the average poundage in the 4–7-foot zone being 695 per acre and that in the 1–3-foot zone 391. Contrary to the rule found usually to hold good in the river, the larger Gastropoda (Viviparidae principally) here showed larger poundages and much larger percentages of valuation totals (74 to 91%) both in the 1–3- and 4–7-foot zones than did the Sphaeriidae. The insects, worms, and Crustacea contributed less than one per cent. of the average poundage figures in the 4–7-foot zone. In the hauls taken inside the four-foot line, leeches and chironomid larvae were especially abundant, and these with a few worms and small Crustacea added, made up over 8% of the weight of the average haul.

Bottom Fauna, 4—7-ft. Zone, Pekin to Copperas Creek Dam, 1915

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Number per sq. yard, Average	177.6	104.0	34.4	316.0 9 collections
Pounds per acre, Average	638.0	52.4	5.1	695.5 9 collections
Per cent. of total, (By weight)	91.7%	7.5%	0.8%	

Bottom Fauna, 1—3-ft. Zone, Pekin to Copperas Creek Dam, 1915

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Number per sq. yard, Average	108.4	135.7	116.8	360.9
Pounds per acre, Average	292.4	67.8	31.2	391.4
Per cent. of total, (By weight)	74.7%	17.0%	8.3%	

(d) Copperas Creek Dam to Havana (16.8 Miles)

Hydrography.—One is at first surprised to find that although at the low water of 1901 there was a decidedly greater decline in elevation of water surface between the foot of the dam at Copperas Creek and Havana *(0.78* inch per mile for 16.8 miles) than between Pekin and the head of the dam (*0.14* inch per mile for 16.2 miles), average flood velocities in the section below the dam are less than in the section of similar length above it. The average velocity at a gage of 18 feet, Peoria, March, 1903, was *83.81* feet per minute between Banner—about 2 miles above the dam—and Havana; and was *114.40* feet per minute between Pekin and Banner. The average slope of high water surface, however, is in close correspondence with these flood velocities—equaling 1.43 inches per mile between Pekin and the dam, as compared with 1.18 inches per mile between the dam and Havana at a gage of 22.6 feet, Peoria, March 31, 1904; and 1.36 inches per mile between Pekin and the dam, compared with 1.11 inches between the dam and Havana at a gage of 19.0 feet in March, 1903. As the low flood velocities through Peoria Lake are a joint consequence of the high bar above the mouth of Farm Creek and the unusual opportunity for expansion in the broad and low flats above it, the retardation of the flood current between Copperas Creek dam and Havana may be explained also as due jointly to the increased impounding area in this section* and to the high mud bar, superimposed upon an older sand bar, which attains its summit about a mile above the mouth of Spoon River. The top of this bar has an elevation only 0.6 foot below the level of the channel floor just below the dam at Copperas Creek, and is 13.8 feet higher than the deepest part of the channel between Liverpool and Havana. The artificial pool behind the dam at Copperas Creek, on the other hand, lies toward the lower end of a stretch of river with relatively steep natural slope, and at the higher gages the flood water moving through that section tends to follow the old slope-lines of water surface as they existed in the years antedating the construction of the dam.

Quite consistently with what has just been noted, both at flood stages and at the 1901 low levels, average slope and current are appreciably greater in the first than in the second half of the 16.8 miles below the dam, the average velocity (66.00 feet per minute) in the eight miles immediately above the Havana bar at a flood gage of 18 feet, Peoria, being in fact not much more than half that in the first eight miles (105.01 feet) and less than that of any other considerable reach of channel in the whole river below Peoria.

In the first seven miles of channel below Copperas Creek dam the upper bottom stratum as shown by the government borings of 1902–1905 was sand and shells or plain sand to a depth of 4 to 21 feet for the greater part of the distance; though dirty sand or sand and shells occurred at a few of the boring stations and was found by us just above

* Table, p. 378.

DECLINE IN ELEVATION OF WATER SURFACE; AND FLOOD VELOCITY

Reach	Interval miles	Average slope—inches per mile			Flood velocity (average feet per minute., gage 18 ft., Peoria)
		Low water 1901	Flood gage Mar. 15, 1903	Flood gage Mar. 31, 1904	
Copperas Creek dam to Havana	16.8	0.78	1.11	1.18	83.81 (18.7 miles)*
Copperas Creek dam to 1 mile above Liverpool	7.8	1.07	....	....	105.01 (10.7 miles)*
1 mile above Liverpool to Havana	9.0	0.53	....	....	66.00 (8.0 miles)*
Pekin to Copperas Creek dam	16.2	0.14	1.36	1.43	114.40 (14.3 miles)*

* Nearest corresponding velocity-reaches (Van Ornum float tests, March, 1903) stop opposite Banner, instead of at Copperas Creek dam.

and just below Senate Island in 1915. In the nine miles of deeper channel between Mile 129 (1 mile above Liverpool) and Havana, the bottom is uniformly mud. The depth of the mud layer is nearly everywhere more than 8 feet, and in extreme instances 13 to 17 feet. The thickness of the mud stratum diminishes to about 7 feet opposite Havana, and a quarter mile farther south the mud quite gives way to a layer of mud and shells, which description of bottom continues nearly uninterrupted for the next 14 or 15 miles. The bottom soils found in the shore zones between Havana and Copperas Creek in 1915 were dark-colored soft mud throughout the 16.8 miles.

Between the dam and Liverpool, bank to bank widths at the low water of 1901 were much as between Pekin and Copperas Creek—usually 550 to around 700 feet; while the greatest depths were under 12 feet. Below Liverpool the river narrows and deepens decidedly, as far as Mile 122.4—the beginning of the expansion formerly known as Havana Lake. In this six miles, widths at the 1901 low levels ranged from 329 to about 500 feet, and depths from 14 to 21 feet. Opposite Havana, for a distance less than half a mile above the mouth of Spoon River, the wide water spread over the Havana bar (Havana Lake) showed an extreme width in the summer of 1901 of about 1,300 feet; while maximum channel depths in the 3 miles above Mile 121 (1 mile above Havana) tapered off southward from more than sixteen to about seven feet. Recent extreme depths at midsummer low gages in the lower half of this reach have ranged from 4 to 5 feet more than the low-water depths given.

Widths and Depths, Copperas Creek Dam to Havana, Low Water, 1901

Miles above Grafton	Station	Width, ft.	Depth, ft. max.
136.6	500 yards below dam.....	677	7.5
136.0	.....	695	7.7
134.3	.....	475	8.6
133.0	.....	586	8.3
132.5	1 mile below foot Senate Island	549	11.8
129.8	.....	603	10.0
129.0	1 mile above Liverpool.....	586	10.8
128.5	.....	528	11.6
128.0	Liverpool	439	14.6
126.9	.....	439	17.0
126.5	.....	...	16.7
126.0	.....	402	14.0
125.7	.....	...	19.0
125.4	.....	340	17.0
125.0	5 miles above Havana.....	329	21.0
124.0	.....	457	15.7
123.0	Middle of "Hogfat Bend".....	475	16.3
122.4	.....	586	10.8
121.0	Upper end "Havana Lake".....	1,299	7.0
120.0	C. P. St. L. Piers, Havana.....	514	12.2

Connecting lake-acreage per mile of river-length between Copperas Creek dam and Havana at the low gages of 1901 largely exceeded that in any other section of river above or below, the figure of 472.1 acres per mile being 57 per cent. more than between Chillicothe and the foot of Peoria Lake and 23 per cent. more than between Havana and the Lagrange dam—the two other reaches with the highest ratings. (Table, p. 378.)

Though the eight or nine mile stretch of river just above Havana has had more shore vegetation at recent summer levels than any other section below Peoria Lake, the amount of vegetation bordering on channel of normal width (excluding such areas as Havana Lake) has not in any recent season been very important. In a local flat stretch of a quarter mile on the west side above Liverpool, where there was more shore vegetation both in 1913 and 1914 than anywhere else between the dam and the head of Havana Lake, the extreme width of the weed strip was about 35 feet, a little less than 5% of the bank to bank width at the time (about 750 feet); while for most of the distance it was not more than 15 feet. Nowhere else between Copperas Creek dam and the head of Havana Lake was there in 1913 or 1914 shore vegetation for any important distance that occupied more than a ten-foot strip next the bank, and there were long stretches with much less than that amount. In the shore zones of the wide water above the mouth of Spoon River there are several acres of Potamogeton on the west side in the most favorable seasons; and on the east side a narrower strip, sometimes up to 50 or 60 feet wide, in a stretch of about 300 yards along the edge of Cook's Island. Even these local areas, relatively to the vastly greater river acreages wholly without aquatic vegetation in the 16.8 miles, are extremely small, and revert largely to open water in all but the driest seasons.

Bottom Fauna.—A total of 16 channel collections and 23 collections in the shore zones (within the 7-foot line) were made in July–October, 1915, between Copperas Creek dam and Havana in cross-section: at

BOTTOM COLLECTIONS, COPPERAS CREEK DAM TO HAVANA
JULY–OCTOBER, 1915

	Channel	4—7-ft. zone	1—3-ft. zone
1. Copperas Creek dam to Mile 129			
Mile 135.2, opposite head of Senate Island	4	2	
Mile 133.6, opposite foot of Senate Island	4	2	
2. Mile 129 to Havana			
Mile 128.5, ½ mile above Liverpool	5	5	4
Mile 123.0, 3 miles above Havana	3	8	2
Total	16	17	6

two stations in the shallower swifter section of 7.8 miles between the dam and Mile 129 (1 mile above Liverpool); and at two stations in the deeper more stagnant section of 9 miles between Mile 129 and Havana.

Although the entire section of over 16 miles is on the average richer in small bottom animals than any other sections heretofore treated, biologically, as well as in its hydrographical characters, it is separable into two well-distinguished portions, the half with the richer channel bottom fauna being the deeper muddier section below Mile 129 and more immediately above the high Spoon-River bar. The average of the poundages per acre at the channel stations in the lower half of the section (5,156.0 lbs.) was in fact nearly six times the average valuation of channel above Mile 129 (878.3 lbs. per acre), and almost fifteen times the average valuation at the channel stations between Chillicothe and the foot of Peoria Lake, Peoria Narrows excepted (345.1 lbs.).

Bottom Fauna, 1915, Copperas Creek Dam to Havana
pounds per acre (average total)

	Channel	4—7-ft. zone	1—3-ft. zone
1. Copperas Creek dam to Mile 129 (7.8 miles)	878.3	1,436.2	No collections
2. Mile 129 to Havana (9 miles)	5,180.8	2,122.0	919.7

In the channel collections both above and below Liverpool the larger Viviparidae made up more than 99% of the weight of the average collection. The Sphaeriidae and the smaller Gastropoda amounted in weight to a mere trace in comparison; while the insects, worms, and small Crustacea accounted for less than half of one per cent. of the average poundages.

Bottom Fauna, Channel, Copperas Creek Dam to 1 Mile above Liverpool, 1915

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Number per sq. yard, Average	263.4	0.3	28.3	292.0 8 coll.'s
Pounds per acre, Average	874.2	0.1	4.0	878.3 8 coll.'s
Per cent. of total, (By weight)	99.5%	trace	0.4%	

Bottom Fauna, Channel, 1 Mile above Liverpool to Havana, 1915

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Number per sq. yard, Average	1,294.0	3.0	171.8	1,468.8 8 coll.'s
Pounds per acre, Average	5,156.0	0.1	24.7	5,180.8 8 coll.'s
Per cent. of total, (By weight)	99.5%		0.4%	

Average bottom-fauna poundages in the 4–7-foot zone above Mile 129 in 1915 (1,436.2 lbs. per acre) were nearly twice those in the channel opposite (878.3 lbs.). Below Mile 129, where they were 2,122.0 lbs. they were less than half the average channel valuation (5,180.8 lbs.). No collections were taken above Mile 129 within the 4-foot line, but between Liverpool and Havana six collections in the 1–3-foot zone showed an average valuation of 917.7 lbs. per acre. In the 4–7-foot zone, both above and below Liverpool, Sphaeriidae were relatively much more abundant than either in the channel or the 1–3-foot zone, making 40 to 80% of the average weight of collections. In the 1–3-foot zone below Mile 129 the weight-composition of the bottom fauna was on the whole nearly identical with that of the channel (Viviparidae and Pleuroceridae 96%; Sphaeriidae and smaller Gastropoda 2.3%; insects, etc., 1.1%).

Bottom Fauna, 4—7-foot Zone, Copperas Creek Dam to 1 Mile above Liverpool, 1915

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Number per sq. yard, Average	302.2	1,212.5	96.0	1,610.4 4 coll.'s
Pounds per acre, Average	814.3	606.2	15.7	1,436.2 4 coll.'s
Per cent. of total, (By weight)	56.6%	42.2%	1.0%	

Bottom Fauna, 4—7-ft. Zone, 1 Mile above Liverpool to Havana, 1915

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Number per sq. yard, Average	120.8	3,537.3	172.0	3,830.1 13 coll.'s
Pounds per acre, Average	319.3	1,776.7	26.0	2,122.0 13 coll.'s
Per cent. of total, (By weight)	15.0%	83.7%	1.2%	

Bottom Fauna, 1—3-ft. Zone, 1 Mile above Liverpool to Havana, 1915

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Number per sq. yard, Average	230.6	38.5	81.0	350.1 6 coll.'s
Pounds per acre, Average	887.6	21.6	10.5	919.7 6 coll.'s
Per cent. of total, (By weight)	96.5%	2.3%	1.1%	

(e) Havana to Lagrange Dam (42.5 Miles)

Hydrography.—While the 42.5 miles of channel between Havana and Lagrange has on the whole a swifter flow than the flatter reaches above Havana, it is separable into three subdivisions which show distinct differences in slope and current:

1. The 17.2 miles between Havana and Sheldon's Grove (approximately Sharp's Landing), which has a low-water slope about the same as Liverpool–Havana (0.53 inch per mile, low water, 1901), and a flood velocity more than twice as great (140.91 feet per minute, March, 1903).

2. The 13.3 miles between Sheldon's Grove and one mile above Beardstown, which had a low-water slope in 1901 (1.08 inches per mile) about double that of the first 17 miles, but a flood velocity (116.06 feet per minute, March, 1903) less than that of the first section.

3. The 12.0 miles between a point one mile above Beardstown and the dam at Lagrange, where the slope of water surface in July, 1901, was only 0.10 inch per mile, but the flood velocity (152.04 feet per second in March, 1903) greater even than between Havana and Sheldon's Grove.

DECLINE IN ELEVATION OF LOW-WATER SURFACE, 1901; AND FLOOD VELOCITY

Reach	Interval miles	Average slope inches per mile	Flood velocity (av. ft. per minute, gage, 18 ft., Peoria)
Havana to Sheldon's Grove	17.2	0.62	140.91 (17.2 miles)
Sheldon's Grove to 1 mile above Beardstown	13.3	1.08	116.06 (14.3 miles)*
1 mile above Beardstown to Lagrange dam	12.0	0.10	152.04 (11.0 miles)*

The principal part of the first subdivision (the 13.8 miles between Havana and the foot of Grand Island) as well as the lower 19.5 miles of the reach (Browning to the dam), together making more than three fourths of the entire reach of 42.5 miles, is comparatively wide and shallow, and has almost entirely sand or sand and shell bottom channel. The muds found at the shore stations in 1915 were both lighter in color and also less soft and deep than the soft shore deposits found above Havana. At the low levels of 1901, depths in the channel between Havana and the foot of Grand Island were as a rule 8 to 10 feet and ran at most a little over 12; while below Browning they ranged usually between 10 and 12 feet and for short distances reached 13 to 15. Depths at recent midsummer low levels have been 2 to 3 feet greater than these. Widths at the low water of 1901 of single channel between Havana and the foot of Grand Island were mostly 600 to 700 feet, and exceeded 750 feet for short stretches; and between Browning and the dam were usually over 700 feet and for good distances between 800 and 1,000.

The central section of about 9 miles of channel lying immediately above the mouth of the Sangamon River (approximate foot of Grand Island to 1 mile above Browning) is much narrower and deeper than the stretches of channel above and below it, and has a mud bottom. Depths in this section of channel at the 1901 low levels were nearly everywhere 15 to 20 feet; while bank to bank width was usually under 600 feet and fell for good distances under 500. The deep natural pool lying above the Sangamon River bar is a homologue of those above the great Farm Creek and Havana bars already described, and is of less moment biologically, in the respect of furnishing a very rich soil for bottom animals, only because the entrance of this large tributary occurs in the very midst of a long stretch of river with naturally steep gradient, where

* Nearest corresponding velocity-reaches (Van Ornum float tests, March, 1903). stop at Beardstown.

both increased velocities and increased flood volumes retard sedimentation and keep the summit of the bar lower than in the other two cases.

Lake and other backwater acreage per mile between Havana and the Lagrange dam (382.4 acres) exceeded at the low water of 1901 that of any other reach of river except the 16.8 miles between Copperas Creek dam and Havana.* The densest distribution of pond acreage occurs in the 9 miles between the foot of Grand Island and the mouth of the Sangamon and falls within the boundaries of greatest channel depths, least flood velocity, softest and darkest-colored bottom deposits, and richest bottom fauna, as shown by our collections of 1915.

WIDTHS AND DEPTHS, HAVANA TO LAGRANGE DAM, LOW WATER, 1901

Miles above Grafton	Station	Width, ft.	Depth, ft. max.	
119.0	1 mile below Havana	658	8.5	1. Havana to foot of Grand Island. Shallow section
118.1	.....	768	8.7	
117.5	.....	549	10.7	
116.0	.....	640	10.0	
115.0	.....	530	12.5	
114.0	.....	732	8.3	
113.5	Head of Grand Island	712	9.0	
111.9	.....	457	9.1	
110.0	.....	...	7.0	West channel only
108.0	.....	...	11.0	
106.5	1/3 mile above foot of Grand Island....	514	14.7	
106.2	Foot of Grand Island	658	12.4	2. Foot of Grand Island to Browning. Narrow, deep section
104.0	.....	475	18.4	
102.8	Sheldon's Grove.....	582	15.6	
101.6	.....	439	20.4	
98.0	Mouth of Sangamon..			
98.2	.....	...	17.0	
97.0	1/4 mile below Browning	494	13.4	3. Browning to Lagrange dam. Wide, shallow section
95.7	1½ miles below Browning	878	8.7	
93.0	.....	750	8.3	
90.3	.....	732	10.2	
89.1	.....	658	13.2	
88.2	1/4 mile below wagon bridge, Beardstown	...	12.8	
86.2	.....	1,006	10.2	
84.2	.....	1,000	13.1	
83.6	.....	514	12.1	
82.6	.....	841	8.5	
81.5	.....	732	10.5	
80.4	.....	732	11.7	
78.8	.....	...	15.0	
78.6	.....	805	11.8	
77.7	250 yards above Lagrange dam	933	11.7	

* Table, p. 378.

Bottom Fauna.—A total of 58 bottom collections, at 9 stations, in cross-section, were taken in 1915 between Havana and the Lagrange dam, distributed between the channel and the shore zones and from north to south as shown in the following table.

COLLECTIONS, HAVANA TO LAGRANGE DAM, 1915

Miles above Grafton	Station	Channel	4—7-ft. zone	1—3-ft. zone
	1. Havana to foot Grand Island (13.8 miles)			
114.7	Opposite foot Matanzas Lake	3	2	
113.7	500 yards above head of Grand Island	3	2	8
	2. Foot Grand Island to Browning (9.0 miles)			
101.0	Opposite foot of Stewart Lake	1	4	2
97.0	1/4 mile below Browning	1	6	2
	3. Browning to Lagrange dam (19.7 miles)			
89.5	1 mile above Beardstown	1	6	2
84.0	Brigg's Landing	2		
83.2	Reich's Landing	2		
80.3	Lagrange Landing	2		
77.7	200 yards above dam	1	2	6
	Total	16	22	20

With reference to the bottom fauna this reach of 42.5 miles may be described as a whole as a section of exceedingly poor channel, bordered on either side by a comparatively rich shore fauna. The average channel poundages of bottom animals taken in 1915 between Havana and the dam at Lagrange was only 22 lbs. per acre, or not much more than one fifteenth of average channel valuation between Chillicothe and the foot of Peoria Lake (345 lbs.), and less than one two-hundredths of the average between Liverpool and Havana (5,180 lbs.). While the channel fauna was about equally poor throughout the 42.5 miles in 1915, the shore fauna (bottom animals within the 7-foot line) was distinctly richest in the central deeper section of river above the mouth of Sangamon River, where the 4–7-foot zone showed figures (365.6 lbs. per acre) about 30% over the average of the 4–7-foot zone for the 42.5 miles, and the 1–3-foot zone a rating (1,613.4 lbs. per acre) nearly four times the 42-mile average, or more in fact than was found anywhere else at that depth between Chillicothe and Grafton. The greater part of the weight of the average collections in the 42 miles, whether from channel or shore zones, consisted of the larger snails (Viviparidae). Though larvae of caddis-flies and nymphs of May-flies were relatively commoner than above Havana, they were not numerous enough anywhere to contribute

importantly to weights, making up at the best only about 6 pounds of the total acre valuation.

BOTTOM FAUNA, 1915, HAVANA TO LAGRANGE DAM
POUNDS PER ACRE, AVERAGE TOTALS

Reach	Channel	4—7-ft. zone	1—3-ft. zone
1. Havana to Lagrange dam (42.5 miles)	22.0	282.6	435.5
2. Foot of Grand Island to Browning (9 miles)	12.5	365.6	1,613.4

BOTTOM FAUNA, 1915, CHANNEL, HAVANA TO LAGRANGE DAM (42.5 MILES)

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Number per sq. yard, Average	5.5	6.0	3.7	15.2 16 coll.'s
Pounds per acre, Average	16.0	3.0	3.0	22.0 16 coll.'s
Per cent. of total, (By weight)	72.7%	13.6%	13.6%	

BOTTOM FAUNA, 1915, 4—7-FOOT ZONE, HAVANA TO LAGRANGE DAM (42.5 MILES)

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Number per sq. yard, Average	73.0	88.0	31.1	192.1 22 coll.'s
Pounds per acre, Average	234.8	42.1	5.7	282.6 22 coll.'s
Per cent. of total, (By weight)	83.0%	14.8%	2.0%	

Bottom Fauna, 1915, 1—3-foot Zone, Havana to Lagrange Dam (42.5 miles)

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Number per sq. yard, Average	99.3	91.1	18.3	208.6 20 coll.'s
Pounds per acre, Average	385.7	44.6	5.2	435.5 20 coll.'s
Per cent. of total, (By weight)	88.5%	10.2%	1.1%	

Bottom Fauna, 1915, Channel, Foot of Grand Island to Browning (9 miles)

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Number per sq. yard, Average	2.7	2.5	1.0	6.2 2 coll.'s
Pounds per acre, Average	1.5	5.0	6.0	12.5 2 coll.'s
Per cent. of total, (By weight)	12.0%	40.0%	48.0%	

Bottom Fauna, 1915, 4—7-foot Zone, Foot of Grand Island to Browning (9 miles)

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Number per sq. yard, Average	92.4	106.4	10.3	209.1 10 coll.'s
Pounds per acre, Average	309.7	53.2	4.5	365.6 10 coll.'s
Per cent. of total, (By weight)	84.2%	14.5%	1.2%	

BOTTOM FAUNA, 1915, 1—3-FOOT ZONE, FOOT OF GRAND ISLAND TO BROWNING (9 MILES)

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Number per sq. yard, Average	327.4	186.2	26.1	539.7 4 coll.'s
Pounds per acre, Average	1,516.0	93.1	4.3	1,613.4 4 coll.'s
Per cent. of total, (By weight)	93.9%	5.7%	0.2%	

(f) LAGRANGE DAM TO GRAFTON (77.5 MILES)

Hydrography.—The average velocity in the 77.5 mile stretch of channel between the Lagrange dam and the mouth of the river in March, 1903, at a gage of about 18 feet, Peoria, (172.30 feet per minute), was more than three times that between Chillicothe and Peoria at the same time (51.94 ft. per minute); more than twice that between Copperas Creek dam and Havana (83.81 ft.); and exceeded that of any other section of channel below Chillicothe except the 9 miles between Peoria and Pekin. The average decline in elevation of water surface at the 1901 low gages between Lagrange and the dam at Kampsville (0.85 inches per mile) was more than three times the average through Peoria Lake; and

DECLINE IN ELEVATION OF LOW-WATER SURFACE, 1901; AND FLOOD VELOCITY

Reach	Interval miles	Av. slope inches per mile	Flood velocity (av. feet per minute), gage, 18 feet, Peoria*
Lagrange dam (below) to Grafton	77.5	...	172.30
Lagrange dam (below) to Kampsville dam (above)	46.1	0.85	164.24
Lagrange dam (below) to Florence	21.9	1.26	146.92
Florence to Kampsville dam (above)	24.2	0.49	183.85
Kampsville dam (below) to Grafton	31.4	2.44	186.91

* Van Ornum float tests, March, 1903.

in the 31 miles below Kampsville (2.44 inches per mile) was more than in the short swift stretch between Peoria and Pekin.

A comparatively well-scoured channel bottom is found most of the way from Lagrange to the mouth, sand, mud and shell, or dirty sand prevailing, and such mud bottom as occurs being usually hard and covered at most with only a very thin layer of recent silt. Inside the 7-foot line in 1915 a soft light-colored silt 2 inches to more than 12 inches deep was found at most of our collecting stations. The most important local stretches of muddy channel in 1915 were 6 miles immediately above the Kampsville dam; and about 4 miles just above the mouth of the river. A less important short section of muddy channel, in

Widths and Depths, Lagrange Dam to Grafton, Low Water, 1901

Miles above Grafton	Station	Width, ft.	Depth, ft. max.
77.0	½ mile below Lagrange dam	658	13.1
72.7	.....	805	8.2
72.3	.....	586	14.0
71.6	.....	658	12.7
71.5	Meredosia	1,006	9.1
68.0	.....	658	15.7
66.5	.....	1,006	10.3
65.5	Naples	787	8.7
64.0	.....	951	6.9
62.5	.....	823	9.3
61.4	.....	567	15.3
59.0	.....	1,024	6.9
55.5	Florence	1,025	8.8
54.5	.....	658	15.6
53.5	.....	975	9.0
47.5	.....	1,116	10.9
44.0	.....	933	10.3
41.2	2 miles below Pearl.....	1,317	10.5
39.2	.....	1,409	12.3
36.7	.....	1,482	10.2
34.5	.....	1,043	14.5
33.0	1 mile above Kampsville....	1,354	11.3
31.8	500 yards above dam.....	1,180	13.7
31.3	300 yards below dam.....	1,317	10.0
29.8	.....	1,006	20.0
25.8	.....	1,079	9.2
21.3	Hardin	1,134	8.1
20.3	.....	1,116	6.5
16.9	.....	1,208	7.2
12.3	.....	768	14.7
11.5	.....	1,061	8.1
10.0	.....	732	19.2
8.5	.....	1,189	7.8
7.3	Foot of Six Mile Island.....	1,610	8.7
6.5	.....	1,098	14.0
5.5	.....	1,263	14.2
4.0	.....	768	14.4
3.0	1 mile above mouth.....	677	18.4

the first mile below Six Mile Island—a local section with little drop in levels at low water—had a deep deposit of light-colored mud in 1913, but apparently much less two years later.

In the 46 miles between Lagrange and Kampsville extreme depths in the channel at the low water of 1901 ranged from 9 to 11 feet as a rule, and did not anywhere exceed 15 feet. Widths at these levels were between 1,000 and 1,400 feet for good stretches, and did not fall below 800 feet for any important distance. Below the Kampsville dam widths were seldom under 800 feet, ranging between 1,000 and 1,200 feet for most of the way, and reaching a maximum of 1,600 in the sluggish section just below Six Mile Island.

Connecting lake and other backwater acreage per mile between Lagrange and the mouth of the Illinois at the low levels of 1901 (219.6 acres per mile between Lagrange and Florence; 180.0 between Florence and Kampsville; 86.9 between Kampsville and the mouth) compared unfavorably with that of most of the river between Chillicothe and Havana.* The greater part of this backwater was leveed and drained between 1901 and 1913, resulting, no doubt, in recent years in a somewhat better scoured channel even than is indicated by the government borings made between 1901 and 1905. As in the 42 miles above the Lagrange dam, shore vegetation between Lagrange and the mouth of the river has in recent years been a negligible quantity.

Bottom Collections, Lagrange to Grafton, 1915

Miles above Grafton	Station	Channel	4—7-ft. zone	1—3-ft. zone
71.7	½ mile above Meredosia	1	2	8
60.0	1½ miles below Valley	1		
55.6	Opposite Florence	1		
54.5	1 mile below Florence	1		
	Total.....	4	2	8
47.7	¾ mile below Bedford	1	6	4
43.2	Opposite foot Pearl Island	1	5	2
36.5	½-way Apple Creek to Panther Cr.	1	6	2
33.0	1 mile above Kampsville	1		
31.6	300 yards above Kampsville dam	1		
	Total.....	5	17	8
25.7	Opposite (west) head Diamond Island	1		
20.6	½ mile below Hardin	1	2	4
11.5	1 mile below foot Mortland Island	1	4	2
9.3	Opposite Bloom's Landing	2		2
8.5	Opposite head Six-Mile Island	1	4	
7.3	Below foot Six-Mile Island	1	2	4
	Total.....	7	12	12
	Grand total.....	16	31	28

* Table, p. 378.

Bottom Fauna.—In August, 1915, a total of 75 collections of the bottom animals were made in cross-section at 15 stations between Lagrange dam and the mouth of the river, as shown in the preceding table.

The bottom-fauna valuations indicated between Lagrange and Grafton by our collections of August, 1915, were almost uniformly poor both in the shore zones and in the channel—the average of the sixteen channel collections being only 6.7 lbs. per acre; that of 31 collections between 4–7-feet, 16.7 lbs.; and that of 28 collections within the 4-foot line, 16.9 lbs. The best local figures for the shore were obtained in the 4–7-foot zone opposite Meredosia, where two hauls averaged 57.5 lbs. per acre; and in the 1–3-foot zone below Kampsville dam, where twelve collections averaged 27.9 lbs. Both in the channel and in the shore zones, if we except the 4–7-foot zone collections opposite Meredosia, Mollusca contributed less or very little more to the average weight of collections than did insects, worms, and small Crustacea, which together made up 63 to 65% of the average weight of collections in those depths zones, with the noted exception. Of the latter group (non-Mollusca) the most important in weight were the larvae of caddis-flies in the channel, and the immature stages of Ephemeridae (willow-flies) in the shore zones. As these were principally of the new broods hatched from eggs deposited by the adults which emerged only a month to six weeks earlier, they contributed less to the weight of collections than they would have done in the same numbers earlier in the summer or later in the fall. The larger snails (Viviparidae and Pleuroceridae) amounted nowhere below Lagrange to more than 5 or 10% of the weight of collections.

Bottom Fauna, 1915, Lagrange to Grafton
pounds per acre (average total)

Reach	Channel	4—7-ft. zone	1—3-ft. zone
1. Lagrange dam to Florence (21.9 miles)	*4**	57.5 *2*	10.1 *8*
2. Florence to Kampsville, above dam (24.2 miles)	12.4 *5*	16.6 *17*	7.5 *8*
3. Kampsville above dam to Grafton (31.4 miles)	6.5 *7*	10.3 *2*	27.9 *12*
Lagrange to Grafton (77.5 miles)	6.7 *16*	16.7 *21*	16.9 *28*

* The Italic figures give the number of collections.

BOTTOM FAUNA, CHANNEL, LAGRANGE TO GRAFTON, 1915
POUNDS PER ACRE

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Lagrange dam to Florence 4 coll.'s	....	....	....	trace
Florence to Kampsville 5 coll.'s	5.0	1.5	5.9	12.4
Kampsville to Grafton 7 coll.'s	....	2.6	3.9	6.5
Lagrange to Grafton 16 coll.'s	0.3	1.6	3.5	5.4
Per cent. of total (by weight)	5.5%	29.6%	64.8%	

BOTTOM FAUNA, 4—7-FOOT ZONE, LAGRANGE TO GRAFTON, 1915
POUNDS PER ACRE

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Lagrange dam to Florence 2 coll.'s	....	57.5	....	57.5
Florence to Kampsville 17 coll.'s	0.6	10.3	5.7	16.6
Kampsville to Grafton 12 coll.'s	....	4.8	5.5	10.3
Lagrange to Grafton 31 coll.'s	Trace	11.2	5.2	16.4
Per cent. of total (by weight)	....	68.2%	31.8%	

BOTTOM FAUNA, 1—3-FOOT ZONE, LAGRANGE TO GRAFTON, 1915
POUNDS PER ACRE

	Viviparidae and Pleuroceridae	Small Gastropoda and Sphaeriidae	Insects, worms, Crustacea	Total
Lagrange dam to Florence 8 coll.'s	....	9.2	0.9	10.1
Florence to Kampsville 8 coll.'s	2.4	0.1	5.0	7.5
Kampsville to Grafton 12 coll.'s	0.3	6.3	21.3	27.9
Lagrange to Grafton 28 coll.'s	0.8	5.3	10.8	16.9
Per cent. of total (by weight)	4.7%	31.3%	63.9%	

(g) GENERAL SUMMARY, ILLINOIS RIVER BOTTOM FAUNA, JULY–OCTOBER, 1915

1. DISTINCTION OF MAIN REACHES

If we have regard only to the larger average differences in weight of the bottom-fauna stocks of 1915, the 180.5 mile stretch of river between Chillicothe and Grafton separates into four principal subdivisions:—First, a section of 43.7 miles between Chillicothe and the dam at Copperas Creek which bears a fairly rich channel- and a similarly rich shore-fauna (channel average, 239 lbs. per acres; 4—7-foot zone, 372 lbs.; 1—3-foot zone, 225 lbs.). Second, a short stretch between Copperas Creek dam and Havana which has an exceedingly rich channel fauna (3,029 lbs. per acre) and a shore fauna far above the average (4—7-foot zone, 1,960 lbs.; 1—3-foot zone, 920 lbs.). Third, 42.5 miles between Havana and the dam at Lagrange with very poor channel (22 lbs. per acre) but with shore as rich as in the first 60 miles (4—7-foot zone, 282 lbs.; 1—3-foot-zone, 435 lbs.). Fourth, in the lower 77.5 miles, a long reach that is extremely poor both in shore and channel (channel, 6 lbs. per acre; both shore zones, 17 lbs.).

Whether in the shore or the channel zones, so far as is shown by the data of 1915, the richest stocks of small bottom-invertebrates are present in the reaches with the least flood slope and velocity, these

factors clearly influencing—more particularly, of course, in the channel—both the depth and softness of the bottom deposits (regarded as a medium or as a substratum for the bottom population), and also the food supply of the bottom animals so far as it is brought to them by sedimentation. In the two richer reaches of river above Havana the average flood velocity in recent years (around 0.9 miles per hour) has been only about 3/5 of that between Havana and Lagrange (1.5 miles per hour), and less than half the average between Lagrange and Grafton (1.9 miles per hour).

Though there is usually, both in the slower and swifter reaches of the river, if we except the cases of some sharp bends, some retardation of current between mid-channel and shore, with accompanying increase in sedimentation and noticeable differences in the composition of the bottom populations, these differences in the less rapid sections above Havana are neither very important quantitatively nor correlated so far as can be seen. The average poundages per acre of bottom animals between Chillicothe and Copperas Creek dam in the channel and the shore zones (channel, 239 lbs.; 4—7-foot zone, 372 lbs.; 1—3-foot zone, 225 lbs.) are in fact so nearly the same that little if any significance can be attached to the differences; while in the 16.8 miles between Copperas Creek and Havana (channel, 3,029 lbs.; 4—7-foot zone, 1,960 lbs.; 1—3-foot zone, 920 lbs.) the differences in weight between the shore and channel stocks are in the reverse of the direction that might be expected. There is, however, a decidedly sharper contrast below Havana between the physical characters of the channel and shore zones, and in and to either side of the stretch of comparatively hard-bottomed channel between Havana and Lagrange a corresponding contrast in the richness of the bottom fauna that is without much question connected with it. In this section of 42.5 miles the 4—7-foot zone (282 lbs. per acre) had stocks thirteen times as rich as those of the channel (22 lbs.); and there was a further large increase shown in the stocks in the 1—3-foot zone.

Certain special influences that may affect the bottom-fauna yields in the river below the Lagrange dam are discussed in a following section.

2. ALL-ZONE AVERAGES AND TOTAL STOCKS

All-zone averages of the bottom-fauna stocks of the four main river reaches below Chillicothe based upon rough acreage-weightings show a figure for the first 43.7 miles below Chillicothe (264 lbs. per acre) about the same as the average for the entire 180.5 miles between Chillicothe and Grafton (261 lbs.); for the 16.8 miles between Copperas Creek dam and Havana about ten times that (2,693 lbs.); for the 42.5 miles between Havana and Lagrange a rate of yield (88 lbs. per acre) about one third of the general river average and about one thirtieth of the rate in the richest section; and for the 77.5 miles below Lagrange (10.4 lbs. per acre) less than one twenty-fifth of the 180 mile average and less

BOTTOM FAUNA, ILLINOIS RIVER, 1915. SIMPLE SINGLE-ZONE AVERAGES

POUNDS PER ACRE

Reach	Miles	Channel zone	4—7-ft. zone	1—3-ft. zone	Average velocity flood gage 18 ft. Peoria ft. per min.	Average velocity miles per hour
Chillicothe to Copperas Creek dam	43.7	239 *30**	372 *83*	225 *17*	80.87	0.9
Copperas Cr. dam to Havana	16.8	3,029 *16*	1,960 *17*	920 *6*	83.81	0.9
Havana to Lagrange	42.5	22 *16*	282 *22*	435 *20*	134.37	1.5
Lagrange to Grafton	77.5	6 *16*	17 *31*	17 *28*	172.30	1.9
Total	180.5 miles					

* The Italic figures give the number of collections.

than one two-hundredth of the rate between Copperas Creek dam and Havana.

Figures for the total stocks present in the combined channel and shore acreage below Chillicothe July–October 1915 (table, p. 18), based on these all-zone weight valuations and on approximate acreages for average July–October levels in 1910—1914, show that out of total stocks equaling 6,988,103 pounds for about 26,700 acres, 92.7 per cent., or 6,480,952 pounds, were in the 60.5 mile section of river above Havana—this constituting only one third of the total length of river studied and less than one third of the total river acreage. Again, of the total bottom-fauna stocks 53.9%, or 3,770,200 pounds, were in the 16.8 miles of river between Copperas Creek and Havana—which comprises less than one tenth of the total distance between Chillicothe and the mouth, and only about one twentieth of the total acreage. The stocks between Havana and Lagrange, 396,880 lbs., for 42.5 miles, made up but 5.6% of the grand total; and those between Lagrange and Grafton, 110,271 lbs., for 77.5 miles, only 1.5 per cent.

Bottom Fauna, Illinois River, 1915. Acreage-weighted All-Zone Averages
pounds per acre

Reach	Miles	Approx. acres Gage, 8 ft. Havana	Estimated part of total under 7 ft. deep	Bottom fauna lbs. per acre (average)
Chillicothe to Copperas Creek dam	43.7	10,268*	1/3	264 *80*†
Copperas Creek dam to Havana	16.8	1,400	1/4	2,693 *39*
Havana to Lagrange	42.5	4,510	1/5	88 *58*
Lagrange to Grafton	77.5	10,603	2/5	10.4 *75*
Chillicothe to Grafton	180.5	26,782	...	261 *252*

Average Chillicothe to Copperas Creek dam, 555 lbs.
Average Copperas Creek dam to Lagrange, 705 lbs.

3. COMPOSITION OF THE BOTTOM FAUNA

In the section of river above Lagrange dam, both in the channel and in the shore zones, the great bulk of the bottom-fauna poundages was made up of Mollusca (Gastropoda and Sphaeriidae), the percentages by

* Includes Peoria Lake.
† The Italic figures give the number of collections.

Bottom-Fauna Stocks, Illinois River Main Reaches, and Grand Total, Chillicothe to Grafton, July—October, 1915

Reach	Miles	Approx. acres Gage, 8 ft. Havana	Bottom fauna lbs. per acre	Total bottom-fauna stocks pounds	Per cent. of total stocks
Chillicothe to Copperas Creek dam	43.7	10,268*	264	2,710,752	38.7%
Copperas Creek dam to Havana	16.8	1,400	2,693	3,770,200	53.9%
Havana to Lagrange dam	42.5	4,510	88	396,880	5.6%
Lagrange dam to Grafton	77.5	10,603	10.4	110,271	1.5%
Chillicothe to Grafton	180.5	26,782	261	6,988,103	
Copperas Creek dam to Grafton	136.8	16,514	259	4,277,351	
Copperas Cr. dam to Lagrange dam	59.3	5,911	705	4,167,080	59.6%
Chillicothe to Havana	60.5	11,668	555	6,480,952	92.7%

* Including Peoria Lake.

weight running in these reaches from 86 to over 99%, and falling below 90% only in the 1—3-foot zone above the Copperas Creek dam. Below the Lagrange dam, where the large Ephemeridae (May-flies) were relatively much more abundant than farther north, the Mollusca percentages dropper to an average range between 35 and 68%.

In the sections above Lagrange, if we except the 4—7-foot zone between Copperas Creek dam and Havana, the larger snails (Viviparidae and Pleuroceridae) accounted for 70 to nearly 100% of the Mollusca totals (by weight). Below Lagrange the Viviparidae (and Pleuroceridae) were largely replaced by Sphaeriidae in all zones, the weight percentages of that group rising to a range between 84 and 100%.

Bottom Fauna, Illinois River, 1915
Percentages of Average Total Valuations by Weight contributed by Mollusca

	Channel	4—7-ft. zone	1—3-ft. zone
Chillicothe to Copperas Creek dam	96.7	97.3	92.1
Copperas Creek dam to Havana	99.5	98.8	98.8
Havana to Lagrange	86.3	98.1	98.9
Lagrange to Grafton	31.6	65.8	35.8

Bottom Fauna, Illinois River, 1915
Composition of Mollusca Totals. (Percentages by Weight*)

Reach	Viviparidae and Pleuroceridae			Sphaeriidae and small Gastropoda		
	Channel	4—7-ft. zone	1—3-ft. zone	Channel	4—7-ft. zone	1—3-ft. zone
Chillicothe to Copperas Creek dam	78.5	78.1	70.7	21.5	21.9	29.3
Copperas Creek dam to Havana	100.0	22.5	97.7	trace	77.5	2.3
Havana to Lagrange	84.3	84.8	89.7	15.7	15.2	10.3
Lagrange to Grafton	15.8	none	13.2	84.2	100.0	86.8

* Pound values on which these percentages are based are shown in following tables.

ILLINOIS RIVER, 1915, CHANNEL
BOTTOM FAUNA, POUNDS PER ACRE. (SUMMARY)

Reach	No. of collections	Viviparidae etc.	Sphaeriidae etc.	Insects etc.	Total	Per cent. Mollusca
Chillicothe to Mossville	8	244.1	70.4	3.1	317.6	99
Narrows to foot of Peoria L.	4	391.6	3.1	5.6	400.3	98
Foot of Peoria L. to Pekin	4	224.6	8.3	20.9	253.8	91
Pekin to Copperas Cr. dam	14	73.3	63.4	8.1	144.8	94
Average*	30	181.4	49.8	8.1	239.3	96.6
Copperas Cr. dam to Liverpool	8	874.2	0.1	4.0	878.3	99
Liverpool to Havana	8	5156.0	0.1	24.7	5180.8	99
Average*	16	3015.1	0.1	14.3	3029.4	99.5
Havana to Lagrange	16	16.0	3.0	3.0	22.0	86.3
Lagrange to Florence	4				trace	
Florence to Kampsville	5	5.0	1.5	5.9	12.4	52
Kampsville to Grafton	7		2.6	3.9	6.5	40
Average*	16	0.3	1.6		5.4	35.1

* Subreach averages each multiplied by number of collections; then sum of products divided by total number of collections.

Illinois River, 1915, 4—7-foot Zone
Bottom Fauna, Pounds per Acre. (Summary)

Reach	No. of collections	Viviparidae etc.	Sphaeriidae etc.	Insects etc.	Total	Per cent. Mollusca
Chillicothe to Mossville	16	97.4	86.7	13.3	197.4	93
Narrows to foot of Peoria L.	4	446.3	55.5	5.8	507.6	98
Foot of Peoria L. to Pekin	4	60.0	136.7	9.6	206.3	95
Pekin to Copperas Cr. dam	9	638.0	52.4	5.1	695.5	99
Average	33	282.5	79.6	9.7	371.8	97.4
Copperas Cr. dam to Liverpool	4	814.3	606.2	15.7	1436.2	98
Liverpool to Havana	13	319.3	1776.7	26.0	2122.0	98
Average	17	435.7	1501.2	23.5	1960.4	98.8
Havana to Lagrange	22	234.8	42.1	5.7	282.6	98.1
Lagrange to Florence	2		57.5		57.5	100
Florence to Kampsville	17	0.6	10.3	5.7	16.6	65
Kampsville to Grafton	12		4.8	5.5	10.3	46
Average	31	trace	11.2	5.2	16.4	68.2

Illinois River, 1915, 1—3-foot Zone
Bottom Fauna, Pounds per Acre. (Summary)

Reach	No. of collections	Viviparidae etc.	Sphaeriidae etc.	Insects etc.	Total	Per cent. Mollusca
Chillicothe to Mossville	9	30.1	61.2	7.9	99.2	92
Narrows to foot of Peoria L.	1					
Foot of Peoria L. to Pekin	None	174.0	9.8	7.4	191.2	96
Pekin to Copperas Cr. dam	7	292.4	67.8	31.2	391.4	92
Average	17	146.5	60.8	17.4	224.7	92.2
Copperas Cr. dam to Liverpool	None					
Liverpool to Havana	6	887.6	21.6	10.5	919.7	98
Average	6	887.6	21.6	10.5	919.7	98.8
Havana to Lagrange	20	385.7	44.6	5.2	435.5	98.9
Lagrange to Florence	8		9.2	0.9	10.1	91
Florence to Kampsville	8	2.4	0.1	5.0	7.5	33
Kampsville to Grafton	12	0.3	6.3	21.3	27.9	24
Average	28	0.8	5.3	10.8	16.9	36.0

The Bottom Fauna of the Lakes and Ponds of the Illinois River Bottom-lands between Copperas Creek Dam and Lagrange, July—October, 1914—1915

1. Hydrography and Physical Features

In the midsummer and autumn months of 1914 and 1915 a total of 266 bottom collections, principally with the mud-dipper, were made in the lakes and ponds and other backwaters in the river bottoms between the head of Clear Lake and the foot of Sangamon Bay, covering a river distance of 39 miles, and representing an ex-river acreage (about 16,000 acres) at a gage of 8 feet, Havana, around one third of the total prevailing at the time between the Copperas Creek and Lagrange dams (about 52,000 acres).

The lakes and backwaters studied, separate naturally on a basis of physical and hydrographical features into five classes:

I. The deeper lakes of the all-bottom-land type, with flat muddy banks on both sides, and with maximum depths at recent midsummer levels between 7½ and 9 feet. The five lakes of this class examined—Clear—Mud, Liverpool, Thompson, Dogfish, and Sangamon Bay—have deep soft black mud bottom in the central deeper portions, and only rarely a little sand near shore. The vegetation, principally Potamogeton and Ceratophyllum, is confined to the rather wide shallow margins, the most of it well within the zone of 0—6 feet. These lakes ranged in size at the low water of 1901 (4.2 ft., Havana) from 275 to about 1,800 acres, and represented in all at that gage about 3,390 acres. At the average gage of July—October, 1910—1914 (approximately 8 ft., Havana), their acreage is somewhere near 2½ times the 1901 figures, or over 8,000 acres, which is close to one seventh of the total lake acreage between Copperas Creek dam and Lagrange, and more than the total river acreage at the same gage in the same distance (about 6,000 acres).

II. The deeper, sand-beach type, bordering on one side against the sandy bluff, and with sandy shore on that side, but with flat muddy banks opposite. The two lakes of this type studied (Quiver and Matanzas) had a total acreage at the low water of 1901 of more than 600 acres), and maximum depths at recent midsummer levels of 8½ to 12 feet. In Quiver Lake there is some sand and large quantities of old shells mixed with the mud in the deep "channel" which is kept open by the water from Quiver Creek during freshets. In Matanzas Lake the central open portion has all a soft black mud bottom. The vegetation in these two lakes is in its character and in its distribution not essentially different from that of the lakes of Class I, though it is inclined to be rather less dense on the average. These lakes receive a comparatively large amount of spring water from the sandy bluff on the east side, and their waters average somewhat clearer and (except at times of invasion by river water) poorer in plankton than the lakes of the all-bottom-land type.

III. The comparatively shallow, weedy lakes, with maximum depths at gage 8 feet, Havana, of about 5 feet. The lakes of this class in which collections were made in 1914 and 1915 (Flag, Seebs, Stewart) represented a total acreage at the low water of 1901 of about 1,500 acres, and at 8 feet, Havana, somewhere near 4,000. All of these lakes went completely dry in seasons of extreme low water before 1900. Both in the shallower and the deeper portions the black bottom deposits contain a much larger percentage of partially decayed dead vegetation than is found in the open waters of the lakes of Class I. In recent midsummer seasons, up to 1914, Flag and Seebs lakes have been almost completely filled with growing vegetation. In Stewart Lake at the same time some open water was to be found in the central deeper portion toward the foot, but much less relatively to the total area than was the case in such lakes as Thompson and other deeper lakes of its type.

IV. The very shallow, very weedy lakes, with greatest depths at the low water of 1910—1914 between 3½ and 4 feet. These lakes (Duck, Dennis, Crane) were little more than lily or flag ponds before 1900, going wholly dry at low water in most seasons before the opening of the Chicago Sanitary Canal. Between August and October, 1914, Duck and Dennis lakes were so filled with mixed vegetation that it was difficult to pass through them with a skiff, even the fallen dead stems of the coarse water-plants being blanketed with living filamentous algae. Crane Lake in 1914 and other recent years has been a vast lily-bed, with its rather more open, but densely shaded bottom sprinkled with dead lily stems and "yorkey-nuts". These three lakes had a low-water acreage in 1901 around 1,200 acres.

V. The shallow dead timber and brush areas first permanently submerged after the opening of the Sanitary Canal in January, 1900. These shallow backwaters, ranging in depth from 1½ to 4 feet over most of their areas, have alternating opener and densely weeded stretches, the prevailing vegetation being Potamogetom and Polygonum. Their location on the ridges between such lakes as Flag and Thompson, and on similar ridges between these lakes and others and the river, makes them in reality littoral, either of the river or of lakes of the preceding classes, as the case may be. Their bottom soil still contains abundant traces of the sticks and dead leaves contributed by the willows and mallows and button-bushes that grew there 20 years ago. The area represented by waters of this type can only, for the present, be roughly estimated. The total area under 4 feet in depth at the July–October levels of recent years between Copperas Creek and Lagrange dams (about 29,700 acres) made up over 50% of the total ex-river acreage, while careful estimates in the case of Thompson Lake as flooded to the same elevation (approx. Havana 8 ft.) indicated that on that gage in this lake these areas made up about 30% of the total land flooded. The dead timber and brush areas studied by us in 1914 and 1915 were all in the vicinity of Havana and were variously contiguous with Clear, Flag, Thompson, Dogfish, and Quiver lakes.

2. Bottom Fauna of the Lakes, by Classes

Class I.—Fifty-three collections from open water over 6 feet in depth in the deeper all-bottom-land lakes of Class I in 1914 and 1915 averaged 222 pounds per acre of bottom animals, after deducting shells of Mollusca. An average about twice as great (441 lbs.) was shown by 78 collections from the 1—6-foot zone, 21 of these hauls coming from open bottom and having an average of 696 lbs. per acre, and 57 from more or less weedy bottom, with an average of 347 lbs. The average of the total of 131 collections from the five lakes, all depths, in both seasons, was 352 pounds. Forty-two of the total 131 collections were taken in 1914 and 89 in 1915.

Thompson Lake, both in 1914 and 1915, easily outranked the other lakes of its class studied in the richness of its bottom fauna, its average of over 540 lbs. per acre, in either season, being more than double the best other lake average in this class, (Dogfish,) and nearly three times the lowest (Liverpool).

Class II.—The two sand-beach lakes (Quiver and Matanzas) showed a combined average for 1914 and 1915, for open water over 6 feet, of 1,667 lbs. per acre, for a total of 27 collections. Of these, 18 were from Quiver Lake, with an average of 2,471 lbs., and 9 from Matanzas Lake, with an average of only 58 lbs. per acre. The combined average of 37 collections, from the 1—6-foot vegetation zone, was 251 lbs., the average of Matanzas again being lower than that of Quiver. The general average, for the total of 64 collections, both lakes, both years, and all depths, was 848 lbs. per acre, or more than twice that of the lakes of Class I. It will be noted, however, that the very high average for this class and for Quiver alone, was largely due to a few enormous hauls of large Viviparidae in the deep "channel" in 1914. These were much reduced in numbers and weight per acre in 1915.

Classes III, IV, V.—The shallow weedy lakes of Class III, Flag, Seebs, and Stewart, averaged only 57 lbs. per acre, combined average of 45 collections, all depths, both seasons; and the very shallow, very weedy lakes (Duck—Dennis, Crane) only 94 lbs. per acre for a total of 10 collections. As will be shown in the next section, however, it was in these shallower, weedier lakes, and in other weedy backwaters, that the shore animals in the weeds (above the bottom) reach their highest figures. In the dead timber and brush areas the bottom-fauna average of 16 collections, 1914—1915 (187 lbs.) was better than in weedy lakes of Classes III and IV, approaching, in fact, the average of the open water of the deep lakes of the all-bottom-land type (222 lbs.).

ILLINOIS VALLEY LAKES, BOTTOM FAUNA, 1914—1915

Class I. Deep, bottom-land type			Pounds per acre			Pounds per acre subdivision, 1—6 ft.		Date collections
Lake	Acreage low water 1901	Max. depth Hav., 8 ft.	Open water over 6 ft.	1—6 ft. zone	All stations	No vegetation	Vegetation	
Clear—Mud	830 a.	8½ ft.	215.6 *8**	250.1 *12*	236.3 *20*	....	250.1 *12*	1915
Liverpool	320 a.	9 ft.	142.2 *6*	149.4 *9*	145.1 *15*	....	149.4 *9*	1915
Thompson	1,800 a.	9 ft.	310.7 *8*	612.9 *26*	541.7 *34*	903.2 *10*	431.5 *16*	1914
Thompson	(1,800 a.)	9 ft.	496.6 *8*	562.0 *19*	542.6 *27*	647.6 *7*	512.4 *12*	1915
Dogfish	165 a.	9 ft.	23.4 *3*	397.5 *5*	257.2 *8*	....	397.5 *5*	1914
Dogfish	(165 a.)	8½ ft.	152.0 *12*	134.3 *3*	148.4 *15*	....	134.2 *3*	1915
Sangamon	275 a.	7½ ft.	106.6 *8*	265.0 *4*	159.4 *12*	265.0 *4*	....	1915
Average	.....	.....	222 *53*	441 *78*	352 *131*	696 *21*	347 *57*	

* The Italic figures give the number of collections.

ILLINOIS VALLEY LAKES, BOTTOM FAUNA, 1914—1915

Class II. Deep, sand-beach type			Pounds per acre			Pounds per acre subdivision, 1—6 ft.		Date collections
Lake	Acreage low water 1901	Max. depth Hav., 8 ft.	Open water over 6 ft.	1—6 ft. zone	All stations	No vegetation	Vegetation	
Quiver	230 a.	12 ft.	2,805.0 *15**	388.3 *17*	1,521.1 *32*	....	388.3 *17*	1914
Quiver	(230 a.)	10 ft.	803.1 *3*	158.7 *14*	272.4 *17*	....	158.7 *14*	1915
Matanzas	390 a.	8½ ft.	58.6 *9*	77.9 *6*	66.3 *15*	....	77.9 *6*	1915
Average	.....	.....	1,667 *27*	251 *37*	848 *64*	.....	251 *37*	

* The Italic figures give the number of collections.

ILLINOIS VALLEY LAKES, BOTTOM FAUNA, 1914—1915

Class III. Shallow, weedy type			Pounds per acre			Pounds per acre subdivision, 1—6 ft.		Date collections
Lake	Acreage low water 1901	Max. depth Hav., 8 ft.	Open water over 6 ft.	1—6 ft. zone	All stations	No vegetation	Vegetation	
Flag	600 a.	5 ft.	....	70.9 *3**		....	70.9 *3*	1914
Flag	(600 a.)	5 ft.	....	27.9 *15*		....	27.9 *15*	1915
Seebs	Very small	5 ft.	....	124.0 *7*		....	124.0 *7*	1914
Seebs	.....	5 ft.	....	25.9 *8*		....	25.9 *8*	1915
Stewart	930 a.	5 ft.	....	73.8 *12*			73.8 *12*	1915
Average	.....	....	....	57 *45*	57 *45*	....	57 *45*	

* The Italic figures give the number of collections.

ILLINOIS VALLEY LAKES, BOTTOM FAUNA, 1914—1915

Class IV. Very shallow, very weedy			Pounds per acre			Pounds per acre subdivision, 1—6 ft.		Date collections
Lake	Acreage low water 1901	Max. depth Hav., 8 ft.	Open water over 6 ft.	1—6-ft. zone	All stations	No vegetation	Vegetation	
Duck—Dennis	260 a.	4 ft.	.....	110.3 *5**	....	....	110.3 *5*	1914
Crane	910 a.	3½ ft.	.....	79.0 *5*	....	....	79.0 *5*	1915
Average	.....	.....	.....	94 *10*	94 *10*	....	94 *10*	
Class V. Dead timber and brush								
		4 ft.	.....	160.9 *6*	....	....	160.9 *6*	1914
		3½ ft.	.....	202.4 *10*	....	....	202.4 *10*	1915
Average	.....	.....	.....	187 *16*	187 *16*	....	187 *16*	

* The Italic figures give the number of collections.

3. General Average Valuation

A simple average (without weighting to compensate for irregularity in distribution of collections within different lake classes) of the total of 266 bottom collections of 1914—1915 from the five classes of lakes and backwaters (including dead timber and brush areas) figures out at 402 lbs. per acre. Since the general average of 848 lbs. per acre for the Class II lakes (Quiver, etc.) applied to but 620 acres at the low water of 1901, while the average of 352 lbs. per acre for the Class I lakes covered 3,390 acres at the same gage, it is evident that a simple average of this sort is unfair and likely to be unduly high. As we have not complete acreage figures for different depths at recent gages prevailing in midsummer, and lack, in particular, exact figures on the dead timber acreage, a close general average of all the lakes and backwaters studied in the two years, based on accurate acreage weightings, can not now be figured. If we assume, however, that on the average the expansion in lake acreage between 4.2 and 8 feet, Havana, is about the same in all of the first four classes of lakes except Class II, we shall not go far wrong in weighting the class average of I to IV, excluding the dead timber and brush areas, with the low-water acreage for 1901. The general bottom-fauna average for Classes I—IV, inclusive, figures out in this way at *285* lbs. per acre. If, again, we assume that the usual ratio of adjacent dead-timber acreage to the total acreage of lakes and backwaters at gage 8 feet, Havana, is about the same as in Thompson Lake (around 30%, estimated), and weight the Class I—IV average (285 lbs.) and the Class V average (187 lbs., dead timber and brush areas) with "per cent." acreage figures on this basis, we obtain a general average of bottom fauna for the two years, for all classes of lakes and backwaters, all depths, of *255* lbs. per acre, or almost exactly the general river average for 180.5 miles below Chillicothe (261 lbs.), but only about one third of the all-zone river average for the 59.3 miles between Copperas Creek and Lagrange dams (705 lbs.).

ILLINOIS VALLEY LAKES, BOTTOM FAUNA, 1914—1915

Class	Acreage low water 1901	Max. depth Hav., 8 ft.	Pounds per acre			Pounds per acre subdivision, 1—6 ft.		Date collections
			Open water over 6 ft.	1—6-ft. zone	All stations	No vegetation	Vegetation	
I Deep bottom-land type	3,390	9 ft.	222 *53**	441 *78*	352 *131*	696 *21*	347 *57*	1914—1915
II Deep, sand-beach type	620	12 ft.	1,667 *27*	251 *37*	848 *64*	....	251 *37*	1914—1915
III Shallow, weedy	1,530	5 ft.	.....	57 *45*	57 *45*	....	57 *45*	1914—1915
IV Very shallow; very weedy	1,170	4 ft.	.....	94 *10*	94 *10*	....	94 *10*	1914—1915
V Dead timber and brush	?	4 ft.	.....	187 *16*	187 *16*	....	187 *16*	1914—1915
Average† I—IV	6,710	....	.....	.....	285 *250*			
Average‡ I—V	....	....	.....	.....	255 *256*			

* The Italic figures give the number of collections. † Acreage-weighted. ‡ Weighted on per cent. basis.

4. Composition of the Bottom Fauna

The proportion of Mollusca to associated animals in the lake collections of 1914—1915 did not run so uniformly high as in the river series of 1915. The Mollusca percentages are highest in the open water of the deeper lakes of Classes I and II, where they run from 84 to 96%. In the weedy zones (1—6 feet) of the deeper lakes the Mollusca percentages were noticeably lower (77%). In the shallower weedy lakes of Classes III and IV the insects and small Crustacea are much more abundant relatively, and the Mollusca ratios drop to 36 and 50%.

Per Cent. Mollusca by Weight (to Total Weight of Collections), Lakes, 1914—1915

	Zone over 6 feet open water	1—6 ft., no vegetation	1—6 ft., vegetation
Class I	84.1	89.8	77.8
Class II	96.8	....	77.5
Class III	....	....	50.7
Class IV	....	....	36.4
Class V	....	....	79.7

The snail fauna of the lakes, like the insect fauna, presents in the average somewhat greater variety than that of the river. Viviparidae made up the largest percentage of the Mollusca totals in the deeper lakes of Classes I and II. In the shallower weedy lakes and in the dead timber areas the ratios of Viviparidae were lower. The smaller snail fauna (smaller Gastropoda, Sphaeriidae) less rarely than in the river consisted almost exclusively of Sphaeriidae—the Valvatidae and Amnicolidae being well represented in most of the lakes studied, and exceeding Sphaeriidae in some cases, in the shallower weedier lakes, both in numbers and weight.

Further details of the composition of the lake bottom-fauna are shown in the detail tables at the end.

Per Cent. of Viviparidae, by Weight, to Total Weight of all Mollusca, Lakes, 1914—1915

	Zone over 6 ft. open water	1—6 ft., no vegetation	1—6 ft., vegetation
Class I	56%	85%	86%
Class II	99%	....	88%
Class III	....	....	62%
Class IV	....	....	61%
Class V	....	....	77%

ILLINOIS VALLEY LAKES, 1914—1915, BOTTOM FAUNA

POUNDS PER ACRE

I. Deep Bottom-land Type. (Zone over 6 feet)

Lake	No. collections	Large Viviparidae etc.	Sphaeriidae etc.	Insects etc.	Total	Per cent. Mollusca
Clear—Mud, 1915	8	17.1	186.8	11.7	215.6	94
Liverpool, 1915	6	24.3	96.7	21.2	142.2	85
Thompson, 1914	8	76.5	140.0	94.2	310.7	69
Thompson, 1915	8	413.9	64.6	18.1	496.6	96
Dogfish, 1914	3	8.0	3.1	12.3	23.4	47
Dogfish, 1915	12	67.1	18.5	66.4	152.0	56
Sangamon, 1915	10	51.2	41.4	14.0	106.6	86
Average	53	104.6	82.2	35.2	222	84.1%

ILLINOIS VALLEY LAKES, 1914—1915, BOTTOM FAUNA

POUNDS PER ACRE

I. Deep Bottom-land Type. (1—6-ft. Zone. No Vegetation)

Lake	No. collections	Large Viviparidae etc.	Sphaeriidae etc.	Insects etc.	Total	Per cent. Mollusca
Thompson, 1914	10	687.1	80.3	135.8	903.2	85
Thompson, 1915	7	610.5	24.9	12.2	647.6	98
Sangamon, 1915	4	145.3	109.5	10.2	265.0	96
Average	21	558.3	67.3	70.6	696	89.8%

I. Deep Bottom-land Type. (1—6-ft. Zone. Vegetation)

Clear—Mud, 1915	12	121.7	110.7	17.7	250.1	93
Liverpool, 1915	9	117.0	4.2	28.2	149.4	85
Thompson, 1914	16	210.0	28.4	193.1	431.5	55
Thompson, 1915	12	481.9	10.0	20.4	512.4	95
Dogfish, 1914	5	336.0	19.1	42.4	397.5	89
Dogfish, 1915	3	none	7.3	126.9	134.2	5
Average	57	233.9	36.1	77.0	347	77.8%

ILLINOIS VALLEY LAKES, 1914—1915, BOTTOM FAUNA

POUNDS PER ACRE

II. Deep, Sand-Beach Type. (Zone over 6 feet)

Lake	No. collections	Large Viviparidae etc.	Sphaeriidae etc.	Insects etc.	Total	Per cent. Mollusca
Quiver, 1914	15	2,754.6	2.9	47.5	2,805.0	98
Quiver, 1915	3	800.0	none	3.1	803.1	99
Matanzas, 1915	9	none	40.6	18.0	58.6	69
Average	27	1,619.2	15.1	32.7	1,667	96.8%

II. Deep, Sand-Beach Type. (1—6-ft. Zone. Vegetation)

Quiver, 1914	17	329.7	33.4	25.2	388.3	93
Quiver, 1915	14	35.5	9.3	113.9	158.7	28
Matanzas, 1915	6	58.4	9.6	9.9	77.9	87
Average	37	174.3	20.4	56.2	251	77.5%

ILLINOIS VALLEY LAKES, 1914—1915, BOTTOM FAUNA

POUNDS PER ACRE

III. Shallow, Weedy Type. (Depth 1—5 ft.)

Lake	No. collections	Large Viviparidae etc.	Sphaeriidae etc.	Insects etc.	Total	Per cent. Mollusca
Flag, 1914	3	none	25.7	45.2	70.9	63
Flag, 1915	15	5.0	none	22.9	27.9	18
Seebs, 1914	7	14.0	15.5	94.5	124.0	24
Seebs, 1915	8	18.5	1.8	5.6	25.9	78
Stewart, 1915	12	41.0	24.4	8.4	73.8	88
Average	45	18.0	10.9	28.1	57	50.7%

ILLINOIS VALLEY LAKES, 1914—1915, BOTTOM FAUNA

POUNDS PER ACRE

IV. Very Shallow, very Weedy Type. (Depth 1—4 ft.)

Lake	No. collections	Large Viviparidae etc.	Sphaeriidae etc.	Insects etc.	Total	Per cent. Mollusca
Duck—Dennis, 1914	5	none	12.4	97.9	110.3	11
Crane, 1915	5	42.0	14.3	22.7	79.0	71
Average	10	21.0	13.3	60.3	94	36.4%

V. Dead Timber and Brush Areas. (Depth 1—4 ft. Vegetation)

Vicinity Havana, 1914	6	29.8	87.1	44.0	160.9	72
Vicinity Havana, 1915	10	167.5	1.3	33.6	202.4	83
Average	16	115.8	33.4	37.5	187	79.7%

The Weed-Fauna of the 1—4-foot Zone of the Illinois Valley Lakes, and the Combined Bottom- and Weed-Fauna Average, August—October, 1914

1. Weed Fauna of the Lakes near Havana.

In the autumn of 1914 a series of quantitative collections of the small invertebrates attached to and scattered between the leaves and stems of the denser growths of coarse vegetation about the margins of the bottom-land lakes near Havana, in depths 1 to 4½ feet, were made at seven stations. These collections were made by inclosing the tops of the plants in a large bucket, lowered about them to a depth of about 9 inches, cutting off the stems a little below the 9-inch level, shaking them out thoroughly in the water obtained by righting the bucket, and then passing the water saved through a fine sieve. Though these collections represent but a fraction of the total "weed fauna", omitting the small insects and other animals occurring between the bottom and the lower limit of the bucket hauls (a distance of 1 to 3 feet), the average valuations obtained in this way were very much above the average *bottom* valuations from the same lakes in any zone, with the single exception of a few hauls from the bottom of the Quiver Lake "channel" in 1914. The general average for the seven stations was in fact 2,118 lbs. per acre, or more than eight times the general average of bottom fauna for the five classes of lakes and backwaters between the head of Clear Lake and Beardstown studied by us in 1914 and 1915 (255 lbs.).

The smaller snails (Amnicolidae, Physidae, and Valvatidae, principally) formed about 50% of the average total by weight. The approximate half of the collections made up of insects (larvae and nymphs) consisted principally of immature Odonata (Agrionidae and small Libellulidae). The only large snails were a few adult *Planorbis trivolvis*, the great bulk of the material being of quite small size and easily available, in that respect, for use as food by young to half-grown as well as adult fishes.

2. Combined Average Valuation of the Bottom- and Weed-Fauna Stocks, and Total Stocks in the Acreage

For the purpose of calculating a general average, and also the total stocks, both of the bottom and weed animals, for the entire lake and other backwater acreage between Copperas Creek dam and Lagrange (approximately 52,700 acres at 8 feet, Havana—the average gage in July—October, 1910—1914), I have assigned the general bottom-fauna average of the twelve lakes studied (255 lbs.) to the entire acreage, as with no levees, and the weed-fauna average of the lakes in the immediate neighborhood of Havana (2,118 lbs.) to the approximate 29,700 acres with depths under 4 feet in the district. An acreage-weighted general average figured in this way stands at 1,447 lbs. per acre, or at

LAKES, VICINITY HAVANA, 1914, WEED FAUNA (UPPER 9 INCHES)

POUNDS PER ACRE

Lake	Number collections	Depth feet	Viviparidae etc.	Amnicolidae Valvatidae Physidae	Insects etc.	Total	Per cent. Mollusca	Date of collection
Between Flag and Thompson	1	2	.....	2,164.1	429.0	2,593.0	83	Oct. 6
Head of Flag	1	1½	.....	481.4	2,036.2	2,517.6	19	Oct. 7
Middle of Duck	1	4	.....	2,421.7	86.2	2,507.9	96	Oct. 2
Foot of Thompson	1	3½	.....	534.6	1,953.6	2,488.2	21	Aug. 12
Foot of Thompson	1	2½	.....	991.4	1,314.0	2,305.4	43	Aug. 14
Middle of Flag	1	4	.....	560.3	705.0	1,265.3	44	Oct. 6
Foot of Thompson	1	4½	.....	320.4	833.4	1,153.8	27	Aug. 14
Average	7	...	.....	1,067.7	1,051.0	2,118	50.8%	

more than twice the all-zone river average for bottom fauna only in the same distance (705 lbs.), and at more than 5½ times the average figures for bottom fauna only in the lakes and other backwaters between the two dams in 1914 and 1915 (255 lbs.).

The total stocks in the entire 52,760 acres of lakes and ponds (acreage as with no levees, substantially same as 1908 rather than 1914—1915, for purpose of comparison with fish yields of that year), 76,358,400 lbs. is more than 10 times the total stocks in the 59.3 miles of river opposite (6,988,103 lbs. for 26,700 acres). Of the total, 13,453,800 lbs., or 17.6%, represents the bottom animals of the full acreage; and 62,904,600 lbs., or 82.3%, represents the small weed animals of the upper 9 inches only, in the rather more than 50% of the total acreage within the 4-foot line.

Bottom- and Weed-Fauna Stocks, Lakes, Copperas Creek Dam to Lagrange (59.3 miles)

	Approx. acreage 8 ft., Havana (No levees)	Average valuation* pounds per acre 1914—1915	Total stocks for acreage in first column†	Per cent. of total
Bottom fauna stocks—all depths	52,760 a.	255	13,453,800	17.6%
Weed fauna stocks—1—4 ft.	29,700 a.	2,118	62,904,600	82.3%
Bottom and weed stocks	52,760 a.	1,447	76,358,400	

The Bottom- and Weed-Fauna of the Littoral Zone of the Deep Glacial Lakes of Northeastern Illinois, August—October, 1916

1. Bottom Fauna

The general average of 119 mud-dipper collections from the zone of 1—7 feet in eight of the deep glacial lakes of northeastern Illinois in August—October, 1916, was only 82.8 lbs. per acre. The six isolated lakes studied (Deep, Cedar, Zurich, Crystal, Long, and Sand lakes) showed the better average (105.8 lbs.), while the two large lakes (Fox and Pistakee) directly open to the channel of Fox River averaged only 54.2 lbs. Sparse vegetation, principally species of Potamogeton, with some Chara, chiefly within the 3-foot line, were present at most of the collecting stations. The bottom varied from sand, gravel or sandy mud, to soft black mud or yellow clay. On the windward side (southeast or west) of most of these lakes there is a more or less sterile clay zone with very

* Based on data from 12 lakes representing around half of the total acreage.
† Equals approximately that of 1908. (Table originally made for comparison with 1908 fish yields.)

scanty vegetation, or none at all, lying between the weedy shore zone and the deep open water, part of it sometimes extending within the 7-foot line.

Valuations considerably better than the average were obtained in restricted areas with more nearly uniform bottom in four of the isolated lakes, the average for clay bottom overlaid with fine decayed vegetation, in Deep Lake being 320 lbs.; for sand and clay, in Cedar Lake, 251 lbs.; for gravel and sand, in Deep Lake, 220 lbs.; and for gravel and sand, in Lake Zurich, 212 lbs.

In its composition the littoral bottom-fauna of these lakes differs most strikingly from that of the Illinois Valley bottom-land lakes in the relatively much lower percentages of Mollusca. Snails made up only

LAKES, NORTHEASTERN ILLINOIS, AUGUST—OCTOBER, 1916, BOTTOM FAUNA
POUNDS PER ACRE
LITTORAL ZONE, 1—7 FEET. SOME VEGETATION

Lake	Number of collections	Large Viviparidae etc.	Sphaeriidae etc.	Insects etc.	Total	Per cent. Mollusca
Deep	7	....	39.8	169.0	208.8	19
Cedar	24	....	24.2	135.6	159.8	15
Zurich	13	9.9	10.0	49.2	69.1	23
Crystal	6	....	16.0	40.4	56.4	28
Long	6	....	1.7	50.7	52.4	3
Sand	10	....	0.6	13.1	13.7	4
Average	66	1.8	16.7	87.1	105.8	17.4%
Pistakee	29	10.8	26.0	42.6	79.4	46
Fox	24	2.3	3.6	18.0	23.9	24
Average*	53	6.9	15.8	31.4	54.2	41.8%

* General (simple) average of 8 lakes (119 collections)=82.8 pounds per acre.

17.4% of the average weight of the hauls at 66 stations in the six isolated lakes; and only 41.8% in the two lakes traversed by the Fox River channel. The snails belonged almost entirely to the smaller-sized species, the larger Pleuroceridae and Viviparidae occurring only very rarely and in small numbers in the hauls. The most abundant families were the Sphaeriidae, Amnicolidae, Valvatidae, and Physidae. The most important insects, measured by weight, were the Trichoptera (caddis-flies), Chironomidae, and large Ephemeridae (May-flies).

(A more complete report on these collections, including also the dredgings in deep water, is being planned for publication later.)

2. Weed Fauna

In August, 1916, we found the shore vegetation of the isolated glacial lakes so generally thin and sparse, as compared with the dense growths of Potamogeton and Ceratophyllum in the Illinois River bottom-land lakes, that it was practically impossible to employ the bucket method of collecting the weed animals used at Havana in 1914. Along the north shores of Pistakee and Nippersink lakes, however, beds of mixed Potamogeton, Myriophyllum, and Ceratophyllum were not uncommon that were fully as dense and that carried not far from as rich a fauna as that of such lakes as Flag and Thompson. The average for the upper 9 inches at two stations in Pistakee and Nippersink lakes in August, 1916 (1,665 lbs. per acre), was only 26% less than the average of the seven weed-fauna stations in the vicinity of Havana in 1914 (2,118 lbs.). Both insects and mollusks constituted an almost insignificant part of the totals, 85% of the weight in one case, and 95% in the other being made up of a single small crustacean—the little fresh-water shrimp, *Hyalella knickerbockeri*. (Table, p. 436.)

Comparison with Outside Bottom- and Weed-Fauna Valuations

1. Bottom- and Weed-Fauna of Oneida Lake. (Baker, 1918)

In the Lower South Bay of Oneida Lake, New York, in 1916, Baker found the richest bottom-fauna within the 6-foot contour. Averaged by weight*, in pounds per acre, sand bottom showed the highest valuations, 143 sixteen square-inch units examined, averaging 387 lbs. Gravel bottom, with 207 lbs., clay bottom, with 188 lbs., and sand and clay, with 210 lbs., were well under sand bottom in richness, but were all much richer than the mud bottom over 6 feet. The mud bottom within the 6-foot line averaged for 27 units 230 lbs. per acre. These valuations much

* Rough, approximate valuations, by present author, from Baker's figures per unit of 16 square inches, on same general basis followed in valuation of Illinois River and lake data, 1914—1916. Average adult size of some of the snails estimated by Mr. Baker. Chironomidae and larvae of Trichoptera lumped and averaged at a round valuation about the average of those of northeastern Illinois glacial lakes.

LAKES, NORTHEASTERN ILLINOIS, 1916. WEED FAUNA (UPPER 9 INCHES)

POUNDS PER ACRE

Lake	Number collections	Depth feet	Viviparidae etc.	Amnicolidae Valvatidae Physidae etc.	Hyalella, insects, etc.	Total	Per cent. Mollusca	Per cent. insects	Per cent. Hyalella	Date
Pistakee north side, upper end	1	3½	....	81.1	2,330.0	2,411.2	3	2	95	Aug. 17
Nippersink north side	1	3½	....	36.0	863.0	899.0	4	11	85	Aug. 18
Average	....	...	....	....	.....	1,655				

exceed the average figures obtained by us in 1916 in the same depth zone in the isolated glacial lakes of northern Illinois (105 lbs.), but do not average much if any better than the best littoral areas in Deep and Cedar lakes (Deep Lake, gravel bottom, 220 lbs., clay and rotten vegetation, 320 lbs.; Cedar Lake, sand and clay bottom, 251 lbs.). They compare very well with the all-depth average (one to eleven feet) for the Illinois Valley lakes of all classes in 1914 and 1915 (255 lbs. per acre), but are exceeded by the general average of bottom fauna only in the 1—6-foot zone of our Class I lakes in the Havana district (441 lbs.); and are far surpassed by the figures for the 1—3- and 4—7-foot zones of the Illinois River between Copperas Creek dam and Havana (1—3-foot zone, 919 lbs.; 4—7-foot zone, 1,960 lbs.). The ratio of Mollusca to the total weight of all animals averaged much higher (38% to 64%) than in the glacial lakes of northern Illinois, but was far under the ratios found in the Illinois River and in the lakes near Havana.

Bottom Fauna of Oneida Lake, 1—6-foot Zone
pounds per acre (our valuations)

	Mollusca	Associated animals	Total	Per cent. Mollusca
Sand bottom	251.3	138.3	389	64
Mud bottom	96.9	133.5	230	42
Sandy clay	81.4	129.3	210	38
Gravel	139.4	68.2	207	67
Clay	75.3	112.7	188	40

While Baker found in Oneida Lake, in a few situations, a weed fauna (total, picked by hand from plants removed from the water) that approached in valuation his bottom-fauna averages for the littoral zones, the average productivity indicated ran very low, and even his heaviest collections (57 to 207 lbs. per acre, our valuations) were far below those obtained by us in the lakes of the Illinois Valley near Havana (2,118 lbs. average) or in the thick Potamogeton and Ceratophyllum beds of Nippersink and Pistakee lakes (1,655 lbs.). Baker's best figures were obtained in the Potamogeton and Myriophyllum, and the bulk of the collections by weight was made up of snails.

2. Bottom Fauna of Lake Mendota. (Muttkowski, 1918)

Average valuations in pounds per acre for the 0—1- and 1—3-meter zones obtained by Muttkowski in Lake Mendota in 1914 and 1915 (60 and 64 lbs. respectively) are slightly higher than our averages of 1916 from the 1—6-foot zone of Fox and Pistakee lakes (54 lbs.), but are well under the average for the six isolated glacial lakes (105 lbs.). Mollusca formed only 4% of the total average weight in the 0—1-meter areas, and 14% in the 1—3-meter zone. The most important groups of animals as measured by weight were the larvae of Chironomidae and Trichoptera.

Bottom fauna of Lake Mendota, Wisconsin. 1—3 meters
pounds per acre (our valuations)

	Mollusca	Others	Total	Per cent. Mollusca
0—1 meter	2.59	57.37	60	4
1—3 meters	9.40	55.12	64	14

3. Marine Bottom-Fauna. Valuations, Denmark (Petersen, 1911—1918)

The marine bottom-fauna valuations, by rough weight, obtained by Petersen 1910 to 1916 included the shells of Mollusca and echinoderms, and require reduction by percentages that probably range at least 33 to 75%. His average valuations for large areas all concern the bottom fauna outside the 6-meter limit, in depths ranging from 10 meters upwards. The average valuation obtained for the Thisted Bredning, years 1910—1916, with an area of 65,000,000 m.^{2} (=16,055 acres) was 3,298 lbs. per acre, rough weight, which would figure down by the percentages mentioned to 800 to 2,200. The Nissum Bredning averages for 110,000,000 m.^{2} (27,170 acres) was somewhat lower, 2,418 lbs., which would stand with deductions of 33 and 75% at 600 or 1,600 lbs.

Petersen's figures for restricted Mytilus and Modiola (a mollusk related to Mytilus) communities—167,556 and 92,036 lbs. per acre, or 83 and 46 tons, respectively, the first in 2-meters depth, the second in 28 meters—by far exceed anything that has been reported elsewhere, so far as we know, for sea or land crops. The figures in the case of the Mytilus haul are equivalent to 552.9 ounces per square yard, or to 0.42 ounce per square inch of bottom area: and those for Modiola, to 303.7 ounces per square yard, or 0.23 ounce per square inch. These figures compare with about 10 ounces per square yard (3,029 lbs. per acre), the net average weight* of the Illinois River channel collections of 1915 between

* Shells of Mollusca deducted.

Copperas Creek dam and Havana. The Mytilus taken by Petersen, as shown by the photographed heaps as they fell out of the bottom sampler, were lying upon each other on the sea bottom.

MARINE BOTTOM FAUNA VALUATIONS (PETERSEN, 1911—1918)
AVERAGES, POUNDS PER ACRE*, LARGE AREAS

	Depth	Acres	Pounds per acre rough weight	Net weight†—after deductions 33 and 75%
Thisted Bredning	over 10 m.	16,055	3,298	800—2,200
Nissum Bredning	over 10 m.	27,170	2,418	600—1,600

PETERSEN'S FIGURES FOR RESTRICTED COMMUNITIES, COMPARED WITH BEST ILLINOIS-RIVER CHANNEL, 1915

	Depth	Pounds per acre	Ounces per square yard	Ounces per square inch	
Mytilus community	2 m.	167,556	552.9	0.42	Rough weight
Modiola community	28 m.	92,036	303.7	0.23	Rough weight
Average Illinois-river channel, Copperas Creek dam to Havana	....	3,029	10	....	Shells deducted

The Food of certain Small Bottom-Invertebrates in the River Channel at Havana and the General Composition of the Detritus

The results of microscopical examination of the stomach and gut contents of a number of the commoner Gastropoda, Sphaeriidae, insect larvae, and others of the small bottom animals of the channel opposite Havana in July, 1914, suggested that settled limnetic plankton plays a more important role in the food of the bottom fauna than seems to be generally recognized. The studies made call for a subdivision of the commoner small bottom-animals at that place into two main groups; the one depending principally upon plankton, and the other more largely upon old detritus, though containing species that make considerable use of

* Pounds per acre calculated by us from Petersen's figures in grams per 0.25 m.²
† Our estimates.

plankton also. The specimens that fall clearly into the group of plankton-feeders represented a rather wide range of families, including Sphaeriidae (as represented by *Sphaerium striatinum*); young Unionidae, about one year old; Bryozoa *(Urnatella gracilis)*; Trichoptera (larvae of Hydropsyche species); Chironomidae (unidentified red larvae); and Planaria. The stomachs of the Sphaeriidae and young Unionidae, though containing principally settled limnetic plankton, held also small amounts of fine dead detritus, as well as many living bacteria, apparently taken in with the latter or with dead planktonts. The insect larvae (caddis and Chironomidae) had enjoyed a clean feed of settled plankton, some of it still alive when eaten. Some living bacteria were seen in the stomachs of the caddis larvae. Species whose stomachs contained nothing but dead detritus included a small Asellus and several tubificid worms. The larger snails of the family Viviparidae (*Campeloma subsolidum* and *Vivipara contectoides*) had eaten large quantities of loose detritus and what appeared to be slime-clotted silt and organic detritus particles such as is commonly found as a thin coating on the shells of the snails themselves and on other hard objects in the mud. Living bacteria, presumably putrefactive or fermentative types, were exceedingly abundant in the material in their stomachs. In small specimens of Vivipara and Campeloma, on the other hand, diatoms and Chlorophyceae from the settling limnetic plankton were not much if any less abundant than old dead detritus. Attached incrusting algae (Pleurococcus and Palmella types) were present in the stomachs of all Viviparidae examined.

In going through samples of the loose bottom-ooze taken with the mud-sucker (see Figure 6, page 372), I was struck with the fact that limnetic plankton, principally diatoms and Chlorophyceae, was, next after the flaky particles of decayed vegetable or animal matter that makes up the dead organic detritus, the most abundant edible element in the ooze, as far as could be determined, being decidedly more important in bulk than normal bottom Protozoa and Rotifera. While bottom Ostracoda were noted in the ooze they were relatively very rare, and limnetic Copepoda, Cladocera, and Rotifera were represented only by fragments or nearly whole carapaces or other chitinous parts.

The enormous numbers of bacteria seen swarming in and among the flaky honeycombed particles of dead organic matter, and inside the bodies of recently dead planktonts, suggest that these minute organisms are themselves not an unimportant part of the food supply of both the plankton- and detritus-eating bottom-animals. Both bacteria and minute pale flagellates and ciliates were also very abundant in the interstices of the slime-bound silt and detritus scum that envelops the upper surface of the shells of a large portion of the living and dead snails. That this material on their own backs is used as food by their fellows is apparently proven by its presence in the stomachs as well as by the numerous tracks of radulae identified in the mantle of scum on the backs of living Vivipara and Campeloma examined.

FOOD OF BOTTOM INVERTEBRATES, ILLINOIS RIVER CHANNEL, HAVANA, JULY, 1914
FOOD FOUND IN STOMACHS OF PLANKTON FEEDERS

Species examined	1. Fine organic detritus (dead matter)	2. Bacteria in detritus or dead plankton	3, 4. Settling limnetic and normal bottom plankton			5. Attached micro-organisms
			Diatoms	Algae	Protozoa Rotifera etc.	
Sphaerium striatinum	Trace	† †	Cyclotella † Navicula † Melosira † etc.	Scenedesmus Coelastrum	Chlamydomonas colorless flagellates* Synchaeta pectinata	
Lampsilis parvus, ½ inch	Trace	† † †	Cyclotella † Navicula † Melosira † etc.	Pediastrum	Chlamydomonas colorless flagellates and ciliates.*	

NOTE.—†††=very abundant; ††=abundant; †=common.

* Normal protozan inhabitants of the thin bottom-ooze.

FOOD OF BOTTOM INVERTEBRATES, ILLINOIS RIVER CHANNEL, HAVANA, JULY, 1914
FOOD FOUND IN STOMACHS OF PLANKTON FEEDERS

Species examined	1. Fine organic detritus (dead matter)	2. Bacteria	3. Settling limnetic plankton			5. Attached micro-organisms
			Diatoms	Algae	Protozoa Rotifera etc.	
Larva of caddis-fly (Hydropsyche sp.)	None	Some	Cyclotella Melosira Navicula etc.	Scenedesmus †	Chlamydomonas †	
Chironomid larva ½ inch, red	None	....	Many species	Scenedesmus †		
Planarian	None	A few	Melosira cells	Coelastrum	Chlamydomonas	
Urnatella gracilis	None	....	Navicula Cyclotella Melosira cells Fragilaria cells Surirella	Scenedesmus	Eudorina Pandorina	

NOTE.—The dagger = common.

FOOD OF BOTTOM INVERTEBRATES, ILLINOIS RIVER CHANNEL, HAVANA, JULY, 1914

FOOD FOUND IN STOMACHS OF DETRITUS FEEDERS

Species examined	1. Fine organic detritus (dead matter)	2. Bacteria (in detritus)	3. Settling limnetic plankton			5. Attached micro-organisms
			Diatoms	Algae	Protozoa Rotifera etc.	
Campeloma subsolidum	† † †	† †	Navicula Synedra Cyclotella Melosira †	Pediastrum Coelastrum Scenedesmus †	Chlamydomonas † Pandorina	Pleurococcus? †
Vivipara contectoides	† †	† †	Navicula Synedra Cyclotella Melosira †	....	....	Pleurococcus † Rhizoclonium
Asellus aquaticus	† †	† †				
Tubificid worm	† † †	† † †				

NOTE.—††† = very abundant; †† = abundant; † = common.

The Nitrogen, Organic Carbon, and other Oxidizable Matter in the Bottom Muds of the River and Lakes below Chillicothe, 1913—1914

1. Bottom Muds of the Illinois River Channel, 1913

Mud samples taken in the Illinois River channel between Chillicothe and Kampsville in March and July—October, 1913, showed a rather wide variation in the amounts of nitrogen present, as expressed in terms of percentage of dry matter, but both in early spring and late summer agreed in showing a higher average above than below Havana. In percentage figures, as stated, five samples from above Havana, all months taken together, averaged 0.306% nitrogen, or 61% richer than the five samples taken on approximately the same dates at stations below Havana, which averaged 0.189%. A lesser actual difference in average nitrogen content is shown for the stations above and below Havana, when we take into account the specific gravity and the moisture percentages of the samples and calculate average values of nitrogen by weight for a given area to a depth (3 inches) supposed to approximate the average depth of cut into the soft bottom by the dipper in taking the samples. The average number of pounds of nitrogen to the acre, figured in this way, was 1,918 for the stations above Havana; and only 26% less, or 1,417 lbs. per acre for the stations between Lagrange dam and Kampsville, in which the specific gravity was visibly higher and the moisture-content lower.

The organic carbon per acre figures out, both above and below Havana, at about 8 times the nitrogen, the averages standing at 14,111 lbs. per acre for the stations above and 11,322 lbs. for the stations below Havana. The total oxidizable matter (which includes both the nitrogen and the organic carbon, as well as various other substances, some of them of a mineral nature), figured in the same way, averaged 48,345 lbs. per acre to a depth of 3 inches in the river channel above Havana, and 31,869 lbs. per acre below Havana.

Compared with the stocks of nitrogen and total oxidizable matter (dry weight) in the muds either above or below Havana, the total acre-poundages of dry matter or nitrogen represented by the bottom invertebrate population of July—October, 1913, are extremely small, however liberally figured. Taking the average bottom-fauna stocks of the river between Chillicothe and Havana (the richest section) as 555 lbs. per acre (see table, page 412), and assuming a dry-matter content of about 10% and a percentage of nitrogen to dry matter of 7%, the dry weight of the average stock of bottom fauna on one acre would stand at 55 pounds, or about 1/900 of the dry weight of the total oxidizable matter per acre in the channel mud of that reach, and the contained nitrogen at less than 4 pounds, or about 1/500 of the total nitrogen per acre.

NITROGEN, ETC., IN MUD, ILLINOIS RIVER CHANNEL, 1913. (AVERAGES)

Reach	Specific gravity	Moisture per cent.	Wet weight 1 liter	Dry weight 1 liter	Nitrogen Mar.—Oct.	Organic carbon July—Oct.	Total oxidizable matter March
	1.55	40.2	1,550 g.	927 g.			
Chillicothe to Havana	Per cent. (terms dry matter)				0.306	2.41	7.71
	Pounds per acre (approximately) to depth 3 inches				1,918	14,100	48,340
	1.67	33.6	1,670	1,108			
Lagrange dam to Kampsville	Per cent. (terms dry matter)				0.189	1.51	4.25
	Pounds per acre (approximately) to depth 3 inches				1,417	11,300	31,860

2. Bottom Muds of the Lakes between Copperas Creek Dam and Beardstown

Comparison of samples from the central portions of eleven lakes between the head of Clear Lake and Browning, May—October, 1914, on the dry-weight percentage basis shows the shallow weedy lakes highest in bottom nitrogen. The average of Flag, Seebs, and Stewart lakes (Class III lakes) in terms of percentage of dry matter, was 0.39%, compared with an average of 0.27% for seven of the deeper, more open lakes of Classes I and II; and with 0.26% for Crane Lake—a lake of the very shallow, very weedy type. The general average of all of the 19 mid-lake samples from eleven lakes of 4 of the five classes (0.32%) was somewhat more than the average for the river channel stations above Havana (0.306%) and nearly twice the river average below Havana (0.189%). The general average of organic carbon in mid-lake samples was 3.89%, comparing with 2.41% for the river channel above Havana, and with 1.51% for the channel below Havana. In organic carbon as in nitrogen, the shallow weedy lakes of Classes III and IV (with 4.30% and 5.19%) averaged well above the deeper lakes of Classes I and II (with 3.67% and 3.09%).

Both in Thompson and Quiver lakes, May—October 1914, the nitrogen and organic carbon figures were considerably highest in samples from the shallower water, the percentages of average difference as between samples from under and over 6 feet in depth amounting in the case of the nitrogen to over 30%, in both Thompson and Quiver lakes, and in the case of the organic carbon to 15% in Thompson and to 52% in Quiver.

Nitrogen and Organic Carbon in Muds, Thompson and Quiver Lakes, May—October, 1914

	Nitrogen Per cent. (in terms of dry matter)		Organic carbon Per cent. (in terms of dry matter)	
	Thompson Lake	Quiver Lake	Thompson Lake	Quiver Lake
Depth over 7 feet	0.325	0.320	4.83	3.46
Average	*8**	*4*	*8*	*4*
Depth 1—6 ft.	0.428	0.440	5.56	5.27
Average	*7*	*4*	*7*	*4*
All depths	0.373	0.400	5.17	4.67
Average	*15*	*4*	*15*	*4*

* The Italic figures give the number of samples.

NITROGEN, ETC., IN MUD OF ILLINOIS VALLEY LAKES, MAY—OCTOBER, 1914
SAMPLES FROM MIDDLE, IN DEEPEST WATER
PER CENT. IN TERMS OF DRY MATTER

	Lake	Samples	Nitrogen	Organic carbon
I. Deeper bottom-land lakes	Clear—Mud	2	0.23	2.93
	Liverpool	1	0.29	2.52
	Thompson	4	0.32	4.83
	Dogfish	1	0.30	3.46
	Sangamon	1	0.22	4.86
	Average (5 lake averages)	..	0.27	3.72
II. Deeper sand-beach lakes	Quiver	4	0.32	3.46
	Matanzas	1	0.24	2.73
	Average (2 lake averages)	..	0.28	3.09
III. Shallow, weedy lakes	Flag	1	0.52	5.48
	Seebs	1	0.35	3.78
	Stewart	1	0.31	3.66
	Average	..	0.39	4.30
IV. Very shallow, very weedy lakes	Crane	1	0.26	5.19
	General average.....		0.32	3.89

NITROGEN, ETC., IN BOTTOM MUDS, 1913—1914,
ILLINOIS RIVER CHANNEL AND LAKES IN VICINITY OF HAVANA

	Nitrogen		Organic carbon		Total oxidizable matter	
	*	†	*	†	*	†
River channel Chillicothe to Kampsville	.247	100	1.87	100	6.32	100
River channel, above Havana	.306	123	2.41	128	7.71	121
River channel, below Havana	.189	76	1.51	80	4.25	67
Eleven lakes, vicinity of Havana, middle	.320	129	3.87	206		
Thompson Lake, middle	.325	131	4.83	258		
Thompson Lake, shore, 1—6 ft.	.428	173	5.56	297		
Thompson Lake, all depths	.373	151	5.17	276		
Quiver Lake, middle	.320	129	3.46	185		
Quiver Lake, shore, 1—6 ft.	.440	178	5.27	281		
Quiver Lake, all depths	.400	161	4.67	249		

The Plankton and other Limnetic Oxidizable Matters carried by the Illinois River Channel at Chillicothe and Havana, 1909—1914

1. STOCKS OF PLANKTON CARRIED PAST HAVANA SEPTEMBER, 1909—AUGUST, 1910

Calculations of the total plankton that passed Havana September, 1909—August, 1910, from the silk-net figures of that year, increased in

* This column gives per cent. in terms of dry matter.
† This column gives percentage on base of Illinois River channel, Chillicothe to Kampsville.

the average ratios found by Kofoid* to hold between silk-net and filter-paper volumes in 1896—1899, show a figure for the twelve-month period (200,477 tons) almost exactly treble the amount (67,750 tons) that was carried in the average year just prior to 1900. Of the twelve months' total about 89 per cent. (179,916 tons) was accounted for during the four months of the spring season, March to June inclusive, during which period 1,474 tons passed every twenty-four hours. The 14,025 tons that passed during the five months July to November inclusive, made up only 6.9 per cent. of the total for the year, but this amounted to ninety-one tons every twenty-four hours, and was enough if all settled to the bottom to supply 1,698 pounds per acre for every acre in the river below Copperas Creek dam at the average gage of that season and year (7.8 ft., Havana). The December—February plankton (6,536 tons) was less than half that of July—November, and only 3.2 per cent. of the total. The full twelve months' total, over 400,000,000 pounds, amounted to 24,279 pounds per acre for each acre of the approximate acreage in the river below Copperas Creek dam at recent under-bank-full stages (8 ft., Havana); or to nearly a hundred times the wet weight of the total bottom-fauna stocks of July—October, 1915, shells deducted, between Copperas Creek and Grafton (4,277,351 pounds). The dry weight of this plankton at two to five per cent. (8,000,000 to 20,000,000 pounds) was twenty to fifty times the estimated dry weight (at 10 per cent.) of the total bottom stocks of 1915 below Copperas Creek (427,735 pounds).

Complete figures for the plankton stocks produced in the full 120 miles between Havana and Grafton would doubtless also include, in addition to the Havana figures, new stocks of no small size added on the way down stream, both as a result of normal multiplication and lake and other backwater contribution. I do not take the fact that all of our down-stream plankton series between 1899 and 1910 showed a large decrease in volumes southward of Havana as ruling out the inference of continued though hidden increase, at a rate merely slower than the rate of decrease due to consumption and settling. The average time of passage between Havana and Grafton was 6.7 days at the average gage of July—November, 1909 (7.81 ft., Havana), and was 4.82 days at the average gage of March—June (Havana, 12.04 ft.). During upward pulses, rates of increase in plankton volumes (c.c. per m^3) were several times recorded both by Kofoid and the writer for the river channel at Havana and for Thompson Lake, both in spring and autumn months, 1896—1910, that amounted to over 25 per cent. in one day; while in extreme cases the increases ran to 60 to 70 per cent. in a single day, or 400 to 500 per cent. in a week.

* Bul. Ill. State Lab. Nat. Hist., Vol. VI., Art. II., 1903, pp. 552-554.

TOTAL PLANKTON PASSING HAVANA, SEPTEMBER, 1909—AUGUST, 1910

Season	Silk plankton c.c. per m.³	Ratio total plankton to silk plankton	Total plankton c.c. per m.³	Gage Havana average	Discharge Havana approx. av. ft. per second	Discharge Havana m.³ per 24 hours	Plankton passing per 24 hours	Plankton whole period	Per cent. of total	Equivalent lbs. per acre, 16,514 acres (river) below Copperas Creek dam. Gage, 8 ft., Havana
December—Feb. 90 days	0.20	6.87:1	1.37	11.96	20,000	48,090,240				791
						Grams...	...65,883,628	13,072,140	...3.2	
						Pounds...	145,246			
						Tons...	72	6,536		
March—June 122 days	13.98	1.99:1	27.82	12.04	20,000	48,090,240				,21,789
						Grams...	1,337,870,476	359,832,778	..89.7	
						Pounds...	...2,949,449			
						Tons...	1,474	179,916		
July—Nov. 153 days	0.87	3.95:1	3.43	7.81	10,000	24,045,120				1,698
						Grams...	..83,160,761	28,050,561	...6.9	
						Pounds...	183,387			
						Tons...	91	14,025		

Year total (pounds) = 400,955,479; per acre (16,514 a.) = 24,279 pounds.
Year total (tons) = 200,477.

2. Stocks of Total Nitrogen and Nitrates in the River Channel at Chillicothe, 1914—1915

Comparison of the plankton figures obtained at Havana September, 1909—August, 1910, with the total nitrogen and nitrate figures for Chillicothe, March, 1914—February, 1915, does not suggest that plankton production in the river between Havana and Peoria has been at all in danger of limitation by the nitrogen supply at any season during recent years. The total nitrogen that passed Chillicothe in the twelve months (67,722 tons) was sufficient, if all metabolized without loss, to produce more than ninety times the actual stocks of plankton that passed Havana in the year 1909—1910 (based on a dry-matter per cent. = 5; nitrogen per cent. in dry matter = 7); while the stock of unused nitrogen in the form of nitrates (22,345 tons) was capable of producing under the same conditions more than twenty times the total plankton that actually passed Havana in 1909—1910. At the dry matter and nitrogen ratios assumed, only about 1,431,983 pounds out of the total of 35,444,859 pounds of nitrogen that passed Chillicothe in the year 1914—1915 would be accounted for as nitrogen in the form of living matter in 400,000,000 pounds of plankton (the approximate amount that passed Havana September, 1909—August, 1910).

If we could distribute the total nitrogen that passed Chillicothe over a river acreage of 26,782 acres (the estimated acreage below Chillicothe at about 8 ft., Havana, the average gage of July—November, 1910—1914), we would have 2,442 pounds per acre in the March—June period; 1,495 pounds per acre July—November; 1,119 pounds per acre December—February; and a total of 5,057 pounds per acre for the year. The nitrates, similarly distributed with correspondingly lesser poundages for the separate seasons, would amount to 1,668 pounds per acre for the twelve months on the same acreage.

The Peoria discharge data entering into the various tables following are the rating-table figures of Jacob A. Harman, as published in the special Report of the Illinois State Board of Health on Sanitary Investigations of the Illinois River, 1901, and more recently used by Alvord and Burdick in the Report of the Rivers and Lakes Commission on the Illinois River and its Bottom-lands, 1915. These figures are considerably higher than recent figures of the U. S. Geological Survey, which we did not have at hand, except in fragmentary form, when the manuscript for the present article was being prepared.

TOTAL NITROGEN PASSING CHILLICOTHE, 1914—1915

Season	Gage Peoria (av.)	Discharge Peoria* cu. ft. per second (av.)	Discharge Peoria cu. ft. per 24 hours	Total nitrogen p. p. m. (av.)	Total nitrogen pounds per cu. ft.	Total nitrogen pounds per 24 hrs.	Total nitrogen tons per 24 hours	
December—February, 1914—1915, 90 days	11.5	17,600	1,520,640,000	3.51	.000219	330,020	166	
		Pounds, whole period, (90 days)						29,971,800
		Pounds per acre (river, including Peoria Lake, below Chillicothe†), 8 ft., Havana						1,119
March—June, 1914, 122 days	13.0	22,900	1,978,560,000	4.34	.000271	536,189	268	
		Pounds whole period (122 days)						65,415,058
		Pounds per acre (river, including Peoria Lake, below Chillicothe), 8 ft., Havana						2,442
July—November, 1914, 153 days	9.5	11,700	1,010,880,000	4.15	.000259	261,817	130	
		Pounds whole period (153 days)						40,058,001
		Pounds per acre (river, including Peoria Lake, below Chillicothe), 8 ft., Havana						1,495
Year total (pounds)								135,444,859
Per acre, (26,782 a.)—pounds								5,057

* Nearest stream-measurement station with full data.
† Approximately 26,782 acres, gage, 8 ft., Havana.

NITRATES PASSING CHILLICOTHE, 1914—1915

Season	Gage Peoria (av.)	Discharge Peoria cu. ft. per second (av.)	Discharge Peoria cu. ft. per 24 hours	Nitrogen as nitrates p. p. m. (av.)	Nitrogen as nitrates pounds per cu. ft.	Nitrogen as nitrates pounds per 24 hours	Nitrogen as nitrates tons per 24 hours	
December—February 90 days	11.5	17,600	1,520,640,000	1.05	.000065	98,841	49	
			Pounds whole period (90 days)					8,895,690
			Pounds per acre, (26,782 a.)*					332
March—June 122 days	13.0	22,900	1,978,560,000	1.71	.000106	209,727	104	
			Pounds, whole period (122 days)					25,586,694
			Pounds per acre, (26,782 a.)					955
July—November 153 days	9.5	11,700	1,010,880,000	1.06	.000066	66,718	33	
			Pounds whole period (153 days)					10,207,854
			Pounds per acre, (26,782 a.)					381

Year total (pounds) 44,690,238
Per acre, (26,782 a.)—pounds 1,668

* River including Peoria Lake, below Chillicothe, 8 ft., Havana.

TOTAL NITROGEN, TOTAL PLANKTON, AND NITRATES PASSING ILLINOIS RIVER POINTS, 1909—1915

Season	Total nitrogen passing Chillicothe 1914—1915	Equivalent in plankton at ratio 1:280	Equals times actual plankton 1909—1910	Total plankton passing Havana 1909—1910	Nitrogen in plankton at ratio 1:280	Nitrates Chillicothe 1914—1915
December—February, 90 days	29,971,800 lbs. 14,985 tons	8,392,104,000 lbs.	× 641	13,072,140 lbs.	46,686 lbs.	8,895,690 lbs. 4,447 tons
March—June, 122 days	65,415,058 lbs. 32,708 tons	18,316,216,240 lbs.	× 59	359,832,778 lbs.	1,285,117 lbs.	25,586,694 lbs. 12,793 tons
July—November, 153 days	40,050,001 lbs. 20,000 tons	11,216,240,280 lbs.	× 399	28,050,561 lbs.	100,160 lbs.	10,207,854 lbs. 5,103 tons
Year	135,444,859 lbs. 67,722 tons	37,924,560,520 lbs.	× 94	400,955,479 lbs.	1,431,983 lbs.	44,690,238 lbs. 22,345 tons

3. Total Stocks of Oxidizable Matter in the River at Chillicothe, 1914—1915

Not only the plankton, but in addition all the other oxidizable matter carried in the stream-flow, whether suspended or dissolved, may be regarded as potential detritus or as potential microorganisms, some portion of which, in some form or other, may be useful as food to the bottom animals or to the organisms on which they themselves feed somewhere in the course of the stream below the sampling point. If the total oxidizable matter at Chillicothe 1909—1914 was in about the same ratio to the total nitrogen as in 1900—1902 (about ten times total nitrogen in the winter and spring months, and seven to nine times the nitrogen figures in midsummer and autumn), we would have had passing Chillicothe in the entire year, March, 1914, to February 1915 a total of 617,137 tons, or over 1,200,000,000 pounds total oxidizable matter, dry weight, or some sixty to a hundred and fifty times the total dry weight of the plankton that passed Havana in the twelve months September, 1909, to August, 1910 (eight million to twenty million pounds). If this enormous total load could be settled out and apportioned equally to the approximate 26,780 acres of river between Chillicothe and Grafton at gage 8 ft., Havana, each acre would receive in the course of the year 46,086 pounds, an average equal to more than seventeen hundred times the average dry weight poundage (about 10 per cent.) of bottom animals per acre (twenty-six pounds) found in the summer of 1915 between Chillicothe and the river's mouth. The employment of vertical instead of surface chemical samples for the determination of loss on ignition would with little question, also, show still higher values of total oxidizable matter than those here figured, particularly in seasons of recession from flood, when the dead suspended organic matter increases heavily in concentration from the surface downward. (See table on p. 456.)

4. The Portion of the Plankton Settled out or Consumed

Basing the computations on percentage decreases in silk-plankton volumes (c.c. per m.^{3}) between Havana and Grafton in June and August 1910, and on rates of increase in discharge between Havana and the mouth of the river in the spring and midsummer months, but taking no account of normal multiplication, there is found for the nine-months growing season, March—November, 1909—1910, a total loss of plankton in the 120 miles below Havana of 243,503,139 lbs., or almost exactly two thirds of the total stocks that passed Havana during the period (387,883,000 lbs.). The dry weight of this lost plankton at 5% (12,175,156 lbs.) amounts to nearly 30 times the dry weight, estimated at 10%, of the bottom animals found in 1915 in approximately the same reach of river in which the loss occurred (total bottom-fauna stocks Copperas dam—Grafton, 1915, 4,277,350 lbs; dry weight at 10%, 427,735 lbs.).

ESTIMATE OF TOTAL OXIDIZABLE MATTER PASSING CHILLICOTHE 1914—1915. (DRY WEIGHT)

Season	Total nitrogen pounds	Factor for total oxidizable*	Total oxidizable matter pounds (dry)	Total oxidizable matter tons (dry)	Total oxidizable matter, lbs. per acre 26,782 acres below Chillicothe 8 ft., Havana
December—February	29,971,800	× 10	299,718,000	....	11,191
March—June	65,415,058	× 10	654,150,580	....	24,424
July—November	40,058,000	× 7	280,406,007	....	10,469
12 months	135,444,859	....	1,234,274,587	617,137	46,084

* Loss on ignition not determined in sanitary chemical samples of 1914—1915. Here estimated on basis of ratios holding in 1900—1902 at Averyville between total nitrogen and total loss on ignition.

That the greater part of the plankton lost, or all of it, was settled out or consumed by larger organisms, rather than that it perished because of any failure of the food supply (particularly nitrogen), is forcibly suggested by two or three considerations: that the losses took place at the greatest rate during the hot season, when the current was least and settling easiest, the rate of loss in August 1910 being 98%; and that instead of there appearing any evidence that the losses were due to diminution in food, both the total limnetic nitrogen and the nitrogen in the form of nitrates increased down-stream both in the spring and midsummer—autumn months in 1914, the nearest year for which we have nitrogen figures. I note here that incomplete studies on the succession of Algae, Protozoa, Rotifera, and Entomostraca in some of our downstream series of plankton-catches suggest that a good part of the loss in plankton below Havana in the spring months during rising pulses of Entomostraca may be due to internal consumption, within the plankton population itself. In May, 1899, in fact, these four groups of microorganisms showed a progression in reaching their maximum abundance, each at a station farther down stream. In the circumstances the presumption seems strong that each pound of Cyclopidae or Rotifera taken near the mouth of the river represents several pounds of smaller plankton species eaten farther up stream. (See tables, pp. 458, 459.)

5. Coincidence of Richer and Poorer Plankton and Bottom-Fauna Reaches in the River below Chillicothe

The fact that there are shown, on a basis of the plankton and bottom-fauna figures (1899—1915), such close coincidences between the location and extent of the richer and poorer plankton and bottom-fauna reaches between Chillicothe and the mouth of the river is not, I think, to be taken too quickly as in itself dependable evidence that the bottom fauna is to any certain and large extent a simple function of the volume or weight of plankton above it. Not only, however, does it appear that both in its bottom fauna and its plankton stocks the sixty odd miles of low-sloped river channel between Chillicothe and Havana is far richer on the average than the lower river reaches, but the decrease down stream, on a broad scale, is in each case found to be progressive, and in fact in substantially similar ratios, if the comparison is made with the midsummer plankton figures. (Table, page 460.) The finding, on the contrary, in August 1913, in a local section of low-sloped channel in the lower river, of a rich plankton-consuming population of Sphaeriidae that was apparently not far from as rich as the best found in 1915 in the middle Illinois Valley district suggests that the very general lack of a suitable substratum for small Mollusca in the channel of the Illinois below Lagrange may have more to do with the decrease of the bottom fauna in the lower river than the decrease in the stock of plankton above it. Other influences that may have some bearing on the average very poor showing made by the bottom fauna in the lower river in 1915 will be taken up farther on.

LOSS OF PLANKTON BETWEEN HAVANA AND GRAFTON, 1909—1910

Season	Total plankton passing Havana pounds	Loss, %, (in c.c. per m^3) Havana to Grafton 1910*	Approx. incr. in discharge Havana to Six Mile Island 1903	Total plankton passing Grafton pounds	Loss of plankton Havana to Grafton pounds	Loss of plankton Havana to Grafton per cent. by weight
March—June 122 days	359,832,778	80%	100%	143,530,438†	216,302,340	61%
July—November 153 days	28,050,561	98%	50%	849,762	27,200,799	97%
Nine months	387,883,339				243,503,139	62%

* Basis June, 1910, for March—June; Aug. 1910, for July—November.
† Calculation made in same manner as in table on page 450.

TOTAL NITROGEN PASSING ILLINOIS RIVER POINTS, 1914. (COMPARISONS ARE WITH CHILLICOTHE.)

	March—June, 122 days			July—November, 153 days		
	Parts per 1,000,000	Average discharge ft. per sec.	Total pounds nitrogen 122 days	Parts per 1,000,000	Average discharge ft. per sec.	Total pounds nitrogen 153 days
Chillicothe	4.34	22,900 (Peoria)	65,415,058	4.15	11,700 (Peoria)	40,058,001
Havana	3.65	Small increase	Small decrease	2.95	Small increase	Decrease
Grafton	4.02	More than doubled	Great increase	2.73	Increase 50% +	Increase*

* Per cent. increase in discharge greater than decrease in p. p. m.

NITRATES PASSING ILLINOIS RIVER POINTS, 1914. (COMPARISONS ARE WITH CHILLICOTHE.)

	March—June 122 days			July—November, 153 days		
	Parts per 1,000,000	Average discharge ft. per sec.	Total pounds nitrogen as nitrates 122 days	Parts per 1,000,000	Average discharge ft. per sec.	Total pounds nitrogen as nitrates 153 days
Chillicothe	1.71	22,900 (Peoria)	25,586,694	1.06	11,700 (Peoria)	10,207,854
Havana	1.93	Increase	Increase	1.06	Increase	Increase
Grafton	2.12	More than doubled	More than doubled	1.46	Increase 50% +	More than doubled

PLANKTON VOLUMES, BOTTOM FAUNA, AND BOTTOM NITROGEN, 3 MAIN REACHES, CHILLICOTHE—GRAFTON

Reach	Plankton volumes, % on base Reach I			Flood velocity	Bottom fauna, 1915		Nitrogen in mud, river channel (to depth 3 in.)	
	May, 1899 (Kofoid)	June, 1910 (Forbes & Richardson)	August, 1910 (Forbes & Richardson)	18 ft. Peoria % basis	All-zone average pounds per acre	Per cent. on base of Reach I	Pounds per acre	Per cent. on base of Reach I
I Chillicothe—Havana 60.5 mi.	100 *6**	100 *10*	100 *7*	100	555	100	1918	100
II Havana—Lagrange 42.5 mi.	44 *4*	38 *3*	8 *3*	150 ca.	88	15	1417†	*73*
III Lagrange—Grafton 77.5 mi.	7 *6*	12 *3*	3 *3*	200 ca.	10.4	2		

* The Italic figures give the number of collections.
† Where there *is* mud.

6. The Plankton of Thompson Lake, 1909—1910

As shown by volumes per cubic meter of silk plankton, based on vertical samples, the middle of Thompson Lake and the river channel at Havana averaged nearly the same in plankton content during the four months March—June, 1910 (Thompson, 12.77 c.c.; river, 13.98 c.c.); while in the July—November period of five months Thompson Lake (5.21 c.c.) averaged about six times as rich as the river (0.87 c.c.). Expressed in terms of pounds per acre to a depth of one meter, these volumes of plankton amount to around 114 lbs. for the lake and 124 lbs. for the river in the March—June period, and to 46 lbs. for the lake and 8 lbs. for the river in July—November. If these quantities of silk plankton are multiplied, both in the case of the river and the lake, by the Kofoid silk-filter-paper ratios for river samples, 1897—1899, the poundages for March—June would be about twice those just given, and for July—November about four times those figures. On the other hand, if depth is taken into account, and total amounts of plankton standing over an acre in the river and the lake to the full average depth at the collecting station are figured, the river acre in March—June will be found to have more plankton standing over it at a given time than an equal area in the central portion of Thompson Lake; and in July—November, about half as much, instead of only one sixth as much, as an acre in the lake.

Plankton Thompson Lake and Illinois River, Havana, 9 months. March—November, 1909—1910

	Gage, Havana average	Depth coll. sta. feet, av.	Depth coll. sta. meters, av.	Silk plankton c.c. per m³	Silk plankton lbs. per acre to depth 1 meter
March—June incl.					
Thompson L.	12.04	12.23	3.7	12.79	114
Illinois River	12.04	22.23	6.7	13.98	124
July—November incl.					
Thompson L.	7.81	8.00	2.4	5.21	46
Illinois River	7.81	18.00	5.4	0.87	8

General Comparison of the Illinois River and its Connecting Lakes in the Food Resources of a Fishery and in Fish Output

Bottom and Limnetic Nitrogen, Plankton, etc.

In the fact that the Illinois Valley lakes, only in a lesser degree than the river itself, are in the spring or later flood-seasons of all but very exceptional years open to receive the sewage-laden water from the upper Illinois River and the Chicago Sanitary Canal, they differ materially from the isolated glacial type of lake and from ponds or other waters which are closed throughout the year to outside sources of nutriment. Such supplies as the river lakes receive, they are able to retain in great measure when their outflow is reduced to little or nothing by the falling of the water levels, but the acquired resources of the river are continually drained away by the current, these losses being especially heavy when the bottom sediments are being stirred up and scoured out in times of flood. Hence the river, as we have seen, is not able to accumulate and hold, even in the reach of extremely low-slope between Copperas Creek dam and Lagrange, surplus stocks of these substances and the residues from their decay as large as the stocks found in the lakes, whether in their deeper open, or in their weedy littoral portions; while in the relatively swifter channel below the Lagrange dam the difference is still further emphasized. So far as the plankton alone is concerned, the surplus stocks on hand at a given time per cubic meter of water in Thompson Lake in 1909—1910 exceeded those in the richest part of the river at Havana, opposite, at whatever season, with the percentage of difference in favor of the lake largest during the more critical season of low productivity, July—November.

That the central Illinois Valley lakes are also to a considerable extent their own furnishers, through the growth and decay of shore vegetation, of their permanent stocks or organic food-materials, is suggested by the size of the annual crops or aquatic vegetation, some of which is rooted, in their shallower zones; as well as by the fact that the stocks of nitrogen, organic carbon and other oxidizable substances in the upper layer of bottom soil are appreciably larger in the weedy littoral than in the deeper open water. The river, whether in the Havana district or above or below, has as offset extremely little weedy shore, where rich stocks of similar kind can originate and decay, or where permanent lodgment can be furnished for settling suspended organic matters carried in from points up stream.

Bottom and Shore Fauna

In the case both of the plankton and of the various other food substances directly or indirectly usable as food by the bottom and shore animals, our data, as far as they go, point clearly to the presence at all

times, both in the river and in the lakes, of surplus stocks of a size far more than sufficient to supply the immediate needs even of vastly richer bottom and shore populations than we found in 1914—1915. But though the river, at least in the region of low slope between Chillicothe and Havana, could thus theoretically produce as large poundages of bottom and shore fauna as the lakes, or even larger, the figures for stocks on hand in the two years mentioned, as well as other evidence, tend rather to prove that the lakes are over their average acreage the better producers, and that their richest fauna is developed in the weedy littoral, where also occur the largest deposits of nitrogen, organic carbon, and other oxidizable matters.

As the margin between the bottom and shore fauna stocks on hand in 1914—1915, even in the most productive lake and river areas, and the food requirements, in kind, of a normal fish population, as of 1908 and neighboring years, seems clearly to be very much smaller than that between the supplies and the needs of the bottom and shore fauna itself, it may be supposed that *figures for stocks on hand* after four or five months' feeding by fishes can not be accepted as they stand, quite as confidently as plankton and nitrogen figures for use as an index of actual total productivity. If this is the case, and if it is also true, as we have reason to think, that the lakes rather than the river are not only the favorite feeding-grounds of the greater part of the large bottom-feeding fishes during the 9-months growing season but also the largest producers of fish flesh, then we should expect that complete figures for *total annual yield* of bottom and shore invertebrates for the river and lake acreage in the Havana district would show a yet greater difference in favor of the lakes than is shown by the figures of stocks on hand as of July—October, 1914—1915. A further point in favor of the lakes is the fact that the very heavy bottom-fauna poundages of the river channel just above Havana consist largely of heavy-shelled snails, which we can not believe are easily made use of as food by any but the largest bottom-feeding fishes. Looked at in this way, the richest river valuations may represent accumulation in the presence of light feeding; while the lower poundages of bottom animals in the lakes opposite may be looked upon as residues from originally much larger stocks, fed down to a closer point than the river stocks, in consequence both of a relatively greater size-availability and of their location within the main-feeding range.

Fish Yields

On a plain acreage basis the total river acreage, at a gage of 10 feet, Beardstown*, between La Salle and Grafton, with equal productivity assumed in both river and lakes, should in 1908† have supplied around 18% of the total fish yield of that year, and the lakes about 82%. In

* Gage selected by Alvord and Burdick as that prevailing on an average one half of the year, 1900—1913.

† Last year for which we have full figures for fish yields.

the same year the river between Copperas Creek dam and Lagrange dam, where the lake acreage is largest relatively to the total, should have furnished about 10% of the total fish yield; the river between La Salle and Copperas Creek dam, about 17%; and the river below Lagrange, about 37%. That the river and lake yields of fish per acre are not equal, however, is suggested with considerable force by more than one consideration. The first of these is the fact that in all the recent years for which we have records the largest poundages of fish per acre have been taken in the reaches with the largest quotas of connecting lake-acreage. Taking the year 1908 as an illustration, and using the figures for separate shipping points obtained by the Illinois Fish Commission in that year, we find for the 59.3 miles of river and lakes between Copperas Creek dam and Lagrange dam, with about 90% of its acreage consisting of lakes and ponds, an average fish-yield per acre for water levels prevailing half the year, of 178.4 pounds; for the 87 miles from La Salle to Copperas Creek dam, with about 83% lakes, 130.4 pounds; and for the lower 77 miles, Lagrange to Grafton, with around 63% lakes, only 69.8 pounds.

If, again, we seek to reach conclusions concerning fish yields for the central Illinois Valley district from the bottom- and shore-fauna data of 1914—1915 we can only suppose that the average yield of the river per acre in recent years between the Copperas Creek and Lagrange dams (with 705 lbs. bottom fauna average) has amounted to less than half the average yield of the lakes opposite (with 1,447 + lbs. bottom- and weed-fauna average). Or, to put it another way, while the river's quota of the total fish catch in this reach on a plain acreage basis in 1908 was 10%, its capacity on a basis of the bottom- and shore-fauna figures of 1914—1915 uncorrected, stands at about 5% of the total.

That both the river and the lake yields of fish per acre have been lower in recent years in the reach above Copperas Creek dam and in the reach below Lagrange than in the district between, is suggested both by our bottom-fauna data from the river and by such incomplete figures as we have from Peoria Lake and Meredosia Bay (1913 and 1914), and also by the fact that the differences in fish yield per acre in 1908 between those two reaches and the Havana section are much greater than the difference in the ratios of lake to total acreage. That, however, the per cent. decrease in fish-yield in the lakes in these two reaches is less than the decrease in the river may perhaps be accepted as circumstantially proven by the greater decrease in the river bottom-fauna figures than in the figures of fish yield themselves.

FISH YIELD, PER CENT. LAKE ACREAGE, AND BOTTOM AND SHORE FAUNA

Reach	Fish catch 1908 lbs. per acre* Ill. Fish Commission	Per cent. lake acreage to total, 1908	Bottom-shore fauna lbs. per acre river, 1915	Bottom-shore fauna lbs. per acre lakes, 1914—1915
La Salle—Copperas Creek dam 87.1 miles	130.4 *73*†	82.9 *91*	264 *37*	Incomplete data
Copperas Cr. dam—Lagrange dam 59.3 miles	178.4 *100*	90.4 *100*	705 *100*	1447 *100*
Lagrange dam—Grafton 77.5 miles	69.8 *39*	62.9‡ *69*	10.4 *1.+*	Incomplete data

* For estimated acreage used see next table.

† Italic figures are Roman figures reduced to per cent.'s on base of middle reach as 100.

‡ This percentage greatly reduced between 1908 and 1915; the others in lesser degree.

River and Lake Acreage (approximate), 1908 at Gage 10 ft. Beardstown, and Fish Catch

Reach	River 1908 acres	Lakes 1908 acres	Total acreage 1908 acres	Per cent. lakes	Per cent. river	Fish catch 1908 lbs. total	Fish catch 1908 lbs. per acre
La Salle—Copperas Creek dam 87.1 mi.	8,200*	39,500†	47,700	82.8	17.2	6,222,000	130.4
Copperas Cr. dam—Lagrange dam 59.3 mi.	5,900	56,000	61,900	90.4	9.6	11,050,000	178.4
Lagrange dam—Grafton 77.5 mi.	10,600	18,000	28,600	62.9	37.1	1,998,000	69.8
La Salle—Grafton 223.9 mi.	24,700	113,500	138,200	82.1	17.9	19,270,000	139.7

* Wide waters of Peoria Lake deducted, giving the river the average number of acres per mile for Henry—Chillicothe and Peoria—Copperas Creek dam.
† Includes wide waters of Peoria Lake.

FISH CATCH, ILLINOIS RIVER AND LAKES, 1908
(ILL. FISH COMM.)

La Salle to Copperas Creek dam		
La Salle to Hennepin	520,000 lbs.	
Henry to Lacon	852,000 "	
Chillicothe	350,000 "	
Peoria	2,800,000 "	
*Pekin (one half)	1,700,000 "	
Total	.....	6,222,000 lbs.
Copperas Cr. dam to Lagrange dam		
*Pekin (one half)	1,700,000 lbs.	
Havana	3,800,000 "	
Bath	1,900,000 "	
Browning	1,700,000 "	
Beardstown	1,950,000 "	
Total	.....	11,050,000 lbs.
Lagrange dam to Grafton		
Meredosia	684,000 lbs.	
Naples to Pearl	409,000 "	
Kampsville to Grafton	905,000 "	
Total	.....	1,998,000 lbs.
Grand total	.....	19,270,000 lbs.

* Pekin catch divided between adjacent reaches because of heavy fishing by Pekin crews in Spring Lake.

BOTTOM- AND SHORE-FAUNA VALUATIONS, 1915, IN TERMS OF MONTHS' SUPPLY FOR ANNUAL INCREMENT IN FISH-WEIGHT OF 150 POUNDS PER ACRE

How close to a critical minimum, from the point of view of the fishery, the stocks of bottom invertebrates in the lower Illinois River had dropped in July—October, 1915, after 5 to 8 months' feeding, is most clearly seen after we have changed the bottom-fauna valuations into terms of months' supply of food for an annual yield of fish somewhat nearly equal to the average for the year 1908 on the acreage estimated to prevail during half of the year. In the tables next following, these calculations are shown as they come out for an annual weight increment of 150 lbs. per acre, the year's feeding being completed in 9 months (March—November), animal food only being used, and an average consumption of five pounds of bottom and shore invertebrates (shells of mollusks deducted) for one pound increase in fish weight being assumed. The feeding ratio (5:1) adopted is the estimate of Walter* for carp and carp-like fishes, living on wild animal food, and is close to the

* Die Fischerei als Nebenbetrieb des Landwirtes u. Forstmannes. 1903.

ratios estimated by Otterstrom* and Kronheim† for trout fed on raw fish or "mostly animal food". The rate of consumption of bottom (or shore) invertebrates per month for the nine-months "year" works out at about 83 pounds:

$$\frac{150 \times 5}{9} = 83.3$$

Expressing the bottom- and shore-fauna valuations of 1915 in multiples of the average monthly consumption rate, we find that in July—October of that year there were 120 miles of the Illinois River below Havana whose average supplies of free-living bottom-invertebrates were sufficient to last at such a rate only 30 days or less beyond the date of collection; and 77.5 miles below Lagrange dam in which there were sufficient stocks to last only 3 days. The much richer stocks in the river above Havana, in spite of the exceedingly low valuations in the lower river, were sufficient to bring up the average supply for the entire 180.5 miles between Chillicothe and Grafton to a figure of 3.1 months—which was also the average for the 60.5 miles between Chillicothe and Copperas Creek dam. In the reach of 59.3 miles between Copperas Creek and Lagrange, where an average supply sufficient for 8.5 months was found, there was a short stretch of 16.8 miles (immediately above Havana) where the stocks were sufficient to last for over 30 months, but a relatively much greater part of the bottom fauna in this locally very rich section was made up of large heavy-shelled Mollusca than was the case in any other part of the river.

In contrast with all of these river figures except those for the 16.8-mile reach between Copperas Creek and Havana, the average stock of twelve lakes between Copperas Creek and Lagrange in July—October, 1914—1915, included a three months' supply of *bottom fauna only* for the whole acreage, a minimum‡ of 25.5 months' supply of shore animals living above the bottom in the weedy acreage within the 4-foot line, and a combined average supply of bottom- and shore-animals sufficient for 17.4 months. (See table, p. 469.)

Supplies of bottom animals that were well above the average of *all* the lakes studied, were shown by the Class I and Class II lakes (of the type of Thompson and Quiver respectively): average of five deeper bottom-land lakes, 4.2 months; average of two deep, sand-beach lakes, 10.2 months. Thompson Lake in 1914 had in August to October a 6.5 months' supply of bottom invertebrates over its entire acreage, and a 25.7 months' supply of weed animals in the 1—4-foot zones—or a combined average supply, on a rough acreage basis, sufficient for 20.8 months. The low rating of bottom-fauna stocks in the very shallow weedy lakes, such as Flag, Duck, Dennis, (0.6 to 1.1 months' supply),

* Fiskerei beretning, 1911, pp. 244—254.
† Bibl. der Gesamten Landwirtschaft, Bd. 34, 1907.
‡ "Weed fauna" catches cover the upper 9 inches only.

was of little importance by comparison with the very high weed-fauna figures from these lakes, the combined bottom and weed fauna averages (if Crane Lake be excepted) apparently including a supply sufficient for not less than 25 to 30 months. (See table, p. 470.)

BOTTOM AND SHORE FAUNA AS FOOD FOR FISHERY

1. ILLINOIS RIVER, JULY—OCTOBER, 1915

Italic figures=months' supply, at 83 lbs. per month, for 9 months' growing season for fish-weight-increment of 150 lbs. per acre, feeding ratio 5:1.

	Miles	Bottom fauna all-zone av. lbs. per acre	Months' supply remaining on date of collection*
Chillicothe—Copperas Cr. dam	43.7	264	*3.1*
Copperas Cr. dam—Lagrange	59.3	705	*8.5*
Copperas Cr. dam—Havana	16.8	2,693	*32.4*
Havana—Lagrange	42.5	83	*1.0*
Lagrange—Grafton	77.5	10.4	*0.1*
Chillicothe—Grafton	180.5	261	*3.1*

HYPOTHETICAL FISH-YIELDS FOR THE RIVER AND LAKE ACREAGE BETWEEN COPPERAS CREEK DAM AND LAGRANGE, ON BASIS OF BOTTOM- AND SHORE-FAUNA STOCKS OF JULY—OCTOBER, 1914—1915

In the table on page 471 are shown figures representing the potential value in fish, at the Walter ratio (5:1), of the bottom- and shore-fauna stocks remaining unconsumed in the central rich district between Copperas Creek dam and Lagrange July—October, 1914—1915, after 5 to 8 months of feeding. The total hypothetical yield of the unconsumed stocks of food thus figured (16,103,580 lbs. of fish, from 80,517,900 lbs. bottom and shore animals), is greater by about 50% than the actual fish catch of 1908 (a banner year) in the same district. Of this total, 831,900 lbs., or 141 lbs. per acre, accrues from about 6,000 acres of river, bearing over 4,000,000 lbs. of small bottom animals; and 15,271,680 lbs., or 289 lbs. per acre, from about 52,000 acres of lakes and other backwaters, bearing not less than 76,000,000 lbs. of small bottom- and shore-animals, of which over 60,000,000 lbs. comes from the upper levels in the shallower, more densely weeded acreage.

* Dates of collection, July—October (after 5 to 8 months' feeding).

BOTTOM AND SHORE FAUNA AS FOOD FOR FISHERY

2. LAKES, COPPERAS CREEK DAM—LAGRANGE, JULY—OCTOBER, 1914—1915

	Bottom fauna		Weed fauna		Combined average	
	Lbs. per acre	Months' supply left on date collection	Lbs. per acre	Months' supply left on date collection	Lbs. per acre	Months' supply left on date collection
I Five deep bottom-land lakes, 1914—1915	352	*4.2**				
Thompson, L., 1914	542	*6.5*	2,135	*25.7*	1,732†	*20.8*
II Two sand beach lakes, 1914—1915	848	*10.2*				
Quiver L., 1914	1,521	*18.3*				
III Three shallow weedy lakes	57	*0.6*	2,125	*25.6*	2,182‡	*26.2*
IV Two very shallow weedy lakes	94	*1.1*	2,508	*30.2*	2,602‡	*31.3*
Average twelve lakes, all classes	255	*3.0*	2,118	*25.5*	1,447†	*17.4*

* For explanation of Italic figures see under heading of previous table.
† Equals acreage-weighted average.
‡ Equals sum of bottom and weed fauna averages (all acreage weedy).

BOTTOM- AND WEED- FAUNA STOCKS AND HYPOTHETICAL FISHERY VALUE, 1915, COPPERAS CR. DAM—LAGRANGE

	Approximate acreage 8 ft. Hav.	Bottom and weed fauna lbs. per acre			Total stocks bottom or weed animals	Hypothetical fish yield, lbs. at 5:1	
		Bottom	Weed	Bottom and weed		Total	Per acre
River all zones	5,900	705	...	...	4,159,500	831,900	141
Lakes, all zones (bottom fauna only)	52,760	255	...	...	13,453,800	2,690,760	51
Lakes, 0—4 ft. (weed fauna only)	29,700	...	2,118	...	62,904,600	12,580,920	423
All lake area (bottom and weed fauna)	52,760	...	...	1,447	76,358,400	15,271,680	289
Total acreage	61,900	...	...	1,300	80,517,900	16,103,580*	260*

* Comparing with 11,050,000 lbs. actual catch in this district in 1908, or 178 lbs. per acre.

The Reproductive Rate of the Bottom Animals

Petersen, writing of the bottom fauna of the Danish fishing grounds, 1911—1918, has expressed the opinion that the bottom animals at least reproduce themselves in weight each year. This conclusion was based by Petersen on the observed fact that from year to year, on the average, similar quantities of bottom animals are found over the same areas, along with similar populations of bottom-feeding fishes. It is perhaps true that more regularity in this respect might be expected in sea-bottom than in the bottom muds of our relatively shallow inland rivers and lakes, which are subject to extremes of temperature; to floods and consequent washing and filling; to disturbance by seining and artificial dredging for navigation channels; and to other unfavorable influences.

With more particular reference to growth rates in small bottom Mollusca, I note that Petersen (1911) remarks that a small Sphaerium-like form, Abra sp., reproduces its weight *several times* in a year; and that F. C. Baker recently observed of very young specimens of the genus Ampullaria, from Ceylon, that they doubled in size in an aquarium in 3 months.

Body weights taken by us of a series of 3 to 63-month specimens of one of the commonest snails from the Illinois River and its connecting lakes, *Vivipara contectoides,* all from late July collections, 1913—1914, indicate an average increase in body weight in one year running from 63 to 100% for the different age-groups studied.

Growth of Vivipara contectoides,* Havana

Age, months (estimated)	Years (estimated)	Maximum length of shell, mm.	Body weight† mg.	Increased weight next 12 months mg.	Per cent. increase next 12 months
3 ca.	0.25	11.5	160	132	82
12—15	1.00—	13.0	292	186	63
24—27	2.00—	15.0	478	438	91
36—39	3.00—	20.0	916	800	87
48—51	4.00—	27.5	1,716	1,734	101
60—63	5.00—	39.0	3,450		

The possibilities of multiplication of this particular snail, if left to itself, are even better shown by an analysis of a collection from Seebs

* All weights are of late July specimens, 1913; 3-months' specimens, evidently from spring brood same year; not possible to determine whether specimens one year and up were from spring or midsummer broods.

† Corrected for loss in alcohol.

Lake containing 100 specimens, ages 3 months and upwards, taken in late July, 1913. Out of 32 specimens over 32 months old, which were capable of 87 to 101% increase in body weight in the next 12 months, 30 carried advanced embryos (midsummer brood) totaling 460.

Figuring the average increase in body weight of young and adult age-groups in the next 12 months at 82.2%, the total body weight of the entire collection (without embryos), which was 72.286 grams at date of collection, would be approximately 131.7 grams one year later. Twelve months' growth in the 460 embryos, assuming that all lived, might be expected to amount in the average individual to at least 4/5 of the average body-weight of 12 to 15-month specimens (see table), or 233.6 mg. each, making the total weight-increment in the 460 embryos in 12 months 107.4 grams. Adding the increase in the embryos and that in the young and adults to the original total body-weight of the collection (72.3 grams) we have, 12 months after date of collection, without making any allowance for increase from a spring brood, a hypothetical total weight of 239.1 grams, or 3.3 times the weight with which we started.

POSSIBILITIES OF GROWTH OF VIVIPARA CONTECTOIDES
(BASED ON COLLECTION FROM SEEBS LAKE, JULY 25, 1913)

Age groups (estimated)	Av. rate increase in body-weight next 12 months	Advanced embryos (of midsummer brood)
32 specimens over 27 months	87—101%	460 (in 30 specimens)
6 specimens, 24—27 mos.	91%	
22 specimens, 12—15 mos.	63%	
40 specimens, 3—4 mos.	82%	
Total, 100 specimens	82.2%	460

Gross weight of collection, 94.0 grams.

Body weight (corrected for loss in alcohol)	72.3 grams
Increase in body-weight next 12 months, at 82.2%	59.4 "
Increase in weight of embryos, next 12 months, at 233.6 mg.* each	107.4 "
Total	239.1 grams
=3.3 × original weight.	

* Equals 4/5 of weight of 12—15-mo. specimens (preceding table).

Changes in the Quantity of the Bottom-Fauna Stocks between 1913 and 1915

Various conditions or agencies besides any heretofore mentioned are doubtless capable of effecting local or temporary changes in the composition and weight of the bottom and shore animals either in the river or the lakes. Among those peculiar to the river may be mentioned the occasional scouring effect of floods in the regions of steepest slope, resultant natural filling at points farther down stream, and the cutting away of the river floor by artificial dredging for channel improvement. In the lakes in which the heaviest commercial fishing is carried on, injury may be done to the bottom animals in the fall of the year by the heavy tackle used. Either in the river or in the backwaters variations of importance in the size of the bottom-fauna stocks may doubtless result from changes in the size of the population of bottom-feeding fishes, these variations being in the direction either of decrease or accumulation. Mortality from other unknown causes no doubt occurs at times, as seemed to be the case with the larger snails in Quiver Lake between July 1914 and July 1915. Of water pollution I note that this was not anywhere an important cause of mortality in the river bottom-fauna below Chillicothe up to and including 1915.

Comparison of such data as we have for the season of 1913 with the more complete results obtained in 1915 indicates generally a quite satisfactory correspondence both in average composition and size of the bottom-fauna stocks in the longer reaches of river channel between Chillicothe and the Kampsville dam, both series of collections bringing out clearly the contrast between the more productive reaches of channel above Havana and the decidedly poorer stretches below. The most important single point of disagreement between the 1913 and 1915 river-figures concerns the finding in 1913 in the lower 30 miles, where in 1915 the average channel stocks of bottom animals were no larger than anywhere else in the lower 75 to 100 miles, of a rich local fauna of Sphaeriidae which apparently compared very well with the best found in the rich Havana district. The presence, only locally, of so rich a bottom population seems to imply the existence in that part of the river of an adequate food supply, and is doubtless sufficiently explained otherwise by its occurrence in a region of less than average slope and velocity and more favorable conditions for sedimentation than are found in most of the lower 100 or more miles of channel. For its disappearance between 1913 and 1915 no certain explanation offers. I note, however, that it is in this wider, and on the average swifter portion of the channel that bar formation is most frequent in the Illinois and that dredging operations for channel maintenance are oftenest carried on. It is also in this part of the river, where for more than 70 miles the far greater portion of the bottom-land lakes had been leveed and drained before 1915, that sudden depletion of sporadic bottom-animal populations might most

easily be accomplished by the waves of large carp and buffalo that advance up the river every spring, and that have in recent years been practically confined within the bank limits of the river itself for feeding range until they have reached a point near or above the Lagrange dam. The last hypothesis as an explanation of this single circumstance, and, as well, of the comparative poverty of the bottom fauna of the entire lower 77 miles of the river, receives some support from the fact that while in 1915 the bottom-fauna stocks between Lagrange and Grafton dropped nearly to the vanishing point, both in the channel and shore zones, between Lagrange and Havana, where there was still a large lake-acreage open to the river, the important decrease in the bottom fauna over Havana district figures was to be seen only in the channel valuations and was apparently, for the most part, explained by the character of the channel bottom.

Only two of the twelve lakes in the Havana district (Thompson and Quiver) were examined both in 1914 and 1915 with sufficient completeness to permit a fair comparison of their stocks of bottom animals as of these two years. While there was an increase of 60% in the average quantities (by weight) in the deeper open water of Thompson Lake from 1914 to 1915, the changes in the shallower zones, and in both the deeper and shallower areas in Quiver Lake, were in the direction of decrease,

Bottom-Fauna Stocks, Illinois River Channel, 1913 and 1915, (July—October)

Reach	Average number individuals per collection.* 1913	Average number individuals per sq. yard 1915	Average pounds per acre 1915†
Chillicothe to Copperas Cr. dam	101 *10*‡	203 33	239
Copperas Creek dam to Havana	280 *6*	880 *16*	3,029
Havana to Lagrange	22 *8*	15 *16*	22
Lagrange to Kampsville	29 *15*	17 *9*	7
Kampsville to Grafton	§ *9*	28 *7*	6

* All hauls with ordinary iron dredge, with coarser mesh bag than in 1915.

† Not figured for 1913 because of less certain quantitative value of 1913-series of collections.

‡ The Italic figures give the number of collections.

§ Five hauls at the foot of Six Mile Island yielded an average of nearly 1,000 specimens of *Musculium transversum* per collection; other hauls, poor.

the percentages ranging from about 30 to 70%. In Quiver Lake the principal part of the decrease resulted from a heavy falling off in the small Mollusca, the unusual numbers of dead snails found everywhere in the lake in 1915 seeming to point to some exceptional mortality from unexplained causes.

BOTTOM FAUNA STOCKS, LAKES IN VICINITY OF HAVANA, 1914 AND 1915, (JULY—OCTOBER)

	Pounds per acre, 1914	Pounds per acre, 1915	Incr. or decr. per cent.	Notes
Thompson Lake over 6 ft.	310 *8**	496 *8*	+60%	No essential change in composition of fauna
1—6 ft., some vegetation	903 *10*	647 *7*	—28%	" " " "
1—6 ft., no vegetation	501 *12*	296 *7*	—40%	" " " "
Quiver Lake over 6 ft.	2,805 *15*	803 *3*	—71%	" " " "
1—6 ft., some vegetation	388 *17*	158 *14*	—59%	Great decrease in snails and increase in Chironomidae between 1914 and 1915

* The Italic figures give the number of collections.

DETAILED VALUATION TABLES

I. Bottom Fauna, Illinois River, 1915

1. Chillicothe to Foot of Peoria Lake

8 Channel Collections, July 26—27 and Aug. 19
Chillicothe to Opposite Mossville

	Number per square yard		Pounds per acre	
Campeloma subsolidum	17.3		51.9	
Lioplax subcarinatus	39.7		47.6	
		88.2		244.1
Vivipara contectoides	28.2		141.0	
Pleurocera sp.	3.0		3.6	
Amnicola emarginata	2.5		trace	
Ancylus sp.	0.7		trace	
Physa sp.	2.5		0.5	
		143.7		70.4
Pisidium sp.	1.5		trace	
Musculium transversum	135.3		67.5	
Young Unionidae	1.2		2.4	
Asellus sp.	0.2		trace	
Small Oligochaeta	8.1		0.2	
Leeches (small spp.)	14.3		2.4	
		26.6		3.1
Caddis larvae (small spp.)	0.2		trace	
Chironomid larvae (smaller spp.)	3.7		0.5	
Chironomid larvae (larger spp.)	0.1		trace	
Total	258.5		317.6	

16 Collections, 4- to 7-ft. Zone, July 26—27, Aug. 17—19, 1915
Chillicothe to Opposite Mossville

	Number per square yard		Pounds per acre	
Campeloma subsolidum	13.3		39.9	
Lioplax subcarinatus	7.1		8.4	
		30.8		97.4
Vivipara contectoides	9.7		48.5	
Pleurocera sp.	0.5		0.6	
Somatogyrus sp.	0.6		0.3	
Valvata spp.	4.3		0.2	
Sphaerium stamineum	0.3		0.2	
		200.3		86.7
Musculium transversum	166.0		83.0	
Musculium jayanum	3.7		2.0	
Pisidium species	25.4		1.0	
Oligochaeta (small spp.)	21.0		0.7	
Leeches (small spp.)	17.6		2.9	
Asellus sp.	0.9		trace	
Hyalella knickerbockeri	7.5		0.3	
		68.7		13.3
Chironomid larvae (small)	9.9		1.3	
Chironomid larvae (large)	5.3		6.6	
Hexagenia, etc. (nymphs)	0.6		0.5	
Caddis-fly larvae (small)	5.3		0.7	
Agrionid nymphs	0.6		0.3	
Total	299.8		197.4	

9 Collections, 1- to 3-ft. Zone, July 26 and 27, 1915
Chillicothe to Opposite Mossville

	Number per square yard		Pounds per acre	
Lioplax subcarinatus	2.2		2.6	
		7.7		30.1
Vivipara contectoides	5.5		27.5	
Somatogyrus sp.	5.5		2.7	
Amnicola emarginata	1.1		trace	
Valvata spp.	7.7		0.4	
		148.6		61.2
Physa sp.	8.8		2.0	
Planorbis trivolvis	2.2		1.5	
Musculium transversum	53.3		26.6	
Pisidium sp.	70.0		28.0	
Oligochaeta (small spp.)	16.6		0.5	
Leeches (small spp.)	27.7		4.7	
Asellus sp.	6.6		0.6	
		76.3		7.9
Chironomid larvae (small)	7.7		1.0	
Agrionid nymph	15.5		0.6	
Coleopterous larvae	1.1		0.5	
Hyalella knickerbockeri	1.1		trace	
Total	232.6		99.2	

3 Channel Collections, July 28 and Aug. 19, 1915
Peoria Narrows

	Number per square yard		Pounds per acre	
Campeloma subsolidum	3.3		9.9	
Lioplax subcarinatus	0.6		0.7	
		23.2		46.3
Vivipara contectoides	3.3		16.5	
Pleurocera sp.	16.0		19.2	
Musculium transversum	1.0	1.0	0.5	0.5
Leeches (small spp.)	11.3		1.9	
		13.3		2.1
Caddis larvae (small spp.)	2.0		0.2	
Total	37.5		48.9	

4 Channel Collections, July 28 and Aug. 19, 1915
Lower Lake, Opposite Eagle Packet Landing

	Number per square yard		Pounds per acre	
Campeloma subsolidum	26.0		78.0	
Lioplax subcarinatus	37.0		44.4	
		134.7		391.6
Vivipara contectoides*	48.2		241.0	
Pleurocera species	23.5		28.2	
Musculium transversum	1.5		0.7	
		5.0		3.1
Sphaerium stamineum	3.5		2.4	
Oligochaeta (small spp.)	17.5		0.6	
Leeches (small spp.)	29.0	48.0	4.9	5.6
Caddis larvae (small spp.)	1.5		0.1	
Total	187.7		400.3	

* A small number of *V. subpurpurea* included.

4 Collections, 4- to 7-ft. Zone, July 26—27, 1915
Lower Lake, Opposite Eagle Packet Landing

	Number per square yard		Pounds per acre	
Campeloma subsolidum	18.5		55.5	
Lioplax subcarinatus	27.5		33.0	
		153.0		446.3
Vivipara contectoides	60.5		302.0	
Pleurocera sp.	46.5		55.8	
Amnicola emarginata	17.5		0.9	
Valvata spp.	53.0		26.5	
Musculium transversum	37.0	167.5	25.9	55.5
Sphaerium stamineum	20.0		0.8	
Pisidium species	40.0		1.4	
Leeches (small spp.)	22.5		3.8	
		52.5		5.8
Asellus sp.	15.0		1.4	
Hyalella knickerbockeri	15.0		0.6	
Total	373.0		507.6	

1 Collection, 1- to 3-ft. Zone, July 28, 1915
Lower Lake, Opposite Eagle Packet Landing

	Number per square yard		Pounds per acre	
Vivipara contectoides	30		150.0	
		50		174.0
Pleurocera sp.	20		24.0	
Planorbis trivolvis	10		7.0	
Pisidium sp.	30	70	1.2	9.8
Valvata spp.	30		1.6	
Hyalella knickerbockeri	100		4.0	
		120		7.4
Leeches (small spp.)	20		3.4	
Total	240		191.2	

2. Foot of Peoria Lake (Wesley) to Pekin

4 Channel Collections, July 22 and Aug. 19, 1915
Wesley to Pekin

	Number per square yard		Pounds per acre	
Campeloma subsolidum	49.0		147.0	
Lioplax subcarinatum	15.0	87.7	18.0	224.6
Vivipara subpurpurea	8.2		41.0	
Pleurocera sp.	15.5		18.6	
Musculium transversum	16.7	16.7	8.3	8.3
Leeches (small spp.)	61.5		10.4	
Chironomid larvae (small spp.)	50.0	129.0	7.0	20.9
Hydropsyche sp. (larva)	17.5		3.5	
Total	233.4		253.8	

4 Collections, 4- to 7-ft. Zone, Aug. 19, 1915
Wesley to Pekin

	Number per square yard		Pounds per acre	
Campeloma subsolidum	10.5		31.5	
Vivipara subpurpurea	4.5	20.0	22.5	60.0
Pleurocera species	5.0		6.0	
Musculium transversum	270.0	272.5	135.0	136.7
Sphaerium stamineum	2.5		1.7	
Leeches (small spp.)	55.0	56.5	9.3	9.6
Hydropsyche sp. (larva)	1.5		0.3	
Total	349.0		206.3	

3. Pekin to Copperas Creek Dam

14 Channel Collections, July 22, 23, 28, and Aug. 19, 1915
Pekin to Copperas Creek Dam

	Number per square yard		Pounds per acre	
Campeloma subsolidum	17.1		51.3	
Lioplax subcarinatus	2.6		3.1	
		28.8		73.3
Vivipara subpurpurea	2.1		10.5	
Pleurocera sp.	7.0		8.4	
Musculium transversum	126.7		63.3	
		126.9		63.7
Young Unionidae	0.2		0.4	
Leeches (small spp.)	42.0		7.1	
Chironomid larvae (small spp.)	6.4	49.8	0.8	8.1
Hydropsyche sp. (larva)	1.4		0.2	
Total	205.5		145.1	

9 Collections, 4- to 7-ft. Zone, July 22, 23, and Aug. 19, 1915
Pekin to Copperas Creek Dam

	Number per square yard		Pounds per acre	
Campeloma subsolidum	95.3		285.9	
Lioplax subcarinatus	8.8		10.5	
		177.6		638.0
Vivipara contectoides	66.7		333.5	
Pleurocera sp.	6.8		8.1	
Musculium transversum	102.6		51.3	
Young Unionidae	0.1	104.0	0.2	52.4
Planorbis trivolvis	1.3		0.9	
Leeches (small spp.)	23.8		4.0	
Chironomid larvae (small spp.)	4.0	34.4	0.5	5.1
Caddis larvae (small spp.)	6.6		0.6	
Total	316.0		695.5	

7 Collections, 1- to 3-ft. Zone, July 22, 23, 1915
Pekin to Copperas Creek Dam

	Number per square yard		Pounds per acre	
Campeloma subsolidum	92.8		278.4	
Lioplax subcarinatus	5.7		6.8	
		108.4		292.4
Vivipara contectoides	1.4		7.0	
Pleurocera sp.	8.5		10.2	
Musculium transversum	135.7	135.7	67.8	67.8
Leeches (large sp)	5.7		11.4	
Leeches (small spp.)	52.8		8.9	
Small oligochaetes	8.5		0.2	
Asellus sp.	17.1		1.6	
		116.8		31.2
Chironomid larvae (large spp.)	8.5		5.6	
Chironomid larvae (small spp.)	15.7		2.1	
Hydropsyche sp. (larva)	7.1		1.4	
Young crayfishes	1.4		Not valued	
Total	360.9		391.4	

4. Copperas Creek Dam to Havana

8 Channel Collections, Aug. 3, 19, 1915
Copperas Creek Dam to one Mile above Liverpool

	Number per square yard		Pounds per acre	
Campeloma subsolidum	161.7		485.1	
Lioplax subcarinatus	17.7		21.2	
Vivipara contectoides	63.8	263.4	319.0	874.2
Vivipara subpurpurea	6.5		32.5	
Pleurocera sp.	13.7		16.4	
Musculium transversum	0.3	0.3	0.1	0.1
Leeches (small spp.)	18.6		3.1	
Asellus sp.	7.2	28.3	0.6	4.0
Chironomid larvae (small spp.)	2.5		0.3	
Total	292.		878.3	

4 Collections, 4- to 7-ft. Zone, Aug. 19, 1915
Copperas Creek Dam to one Mile above Liverpool

	Number per square yard		Pounds per acre	
Campeloma subsolidum	160.5		446.7	
Lioplax subcarinatus	60.7		72.8	
Vivipara contectoides	50.0	302.2	250.0	814.3
Vivipara subpurpurea	2.0		10.0	
Pleurocera sp.	29.0		34.8	
Musculium transversum	1212.5	1212.5	606.2	606.2
Leeches (small spp.)	76.0	96.7	12.9	15.7
Chironomid larvae (small spp.)	20.7		2.8	
Total	1611.4		1436.2	

8 Channel Collections, July 31 and Aug. 3, 4, 1915
One Mile above Liverpool to Havana

	Number per square yard		Pounds per acre	
Campeloma subsolidum	280.0		840.0	
Lioplax subcarinatus	74.7	1294.0	89.6	5156.0
Vivipara contectoides*	815.6		4078.0	
Pleurocera sp.	123.7		148.4	
Amnicola emarginata	3.0	3.0	0.1	0.1
Leeches (small spp.)	106.7		18.1	
Asellus sp.	64.5	171.8	6.1	24.7
Hexagenia bilineata (nymph)	0.6		0.5	
Total	1468.8		5180.8	

* Including a few *V. subpurpurea.*

13 Collections, 4- to 7-ft. Zone, July 31 and Aug. 4, 1915
One Mile above Liverpool to Havana

	Number per square yard		Pounds per acre	
Campeloma subsolidum	48.8		164.4	
Lioplax subcarinatus	41.9		50.2	
		120.8		319.3
Vivipara contectoides	22.8		114.0	
Pleurocera sp.	7.3		8.7	
Planorbis trivolvis	0.4		0.2	
Musculium transversum	3496.9	3537.3	1748.5	1776.7
Sphaerium stamineum	40.0		28.0	
Leeches (small spp.)	131.6		22.3	
Asellus sp.	38.9	172.0	3.7	26.0
Hyalella knickerbockeri	1.5		trace	
Total	3830.1		2122.0	

6 Collections, 1- to 3-ft. Zone, July 31 and Aug. 4, 1915
One Mile above Liverpool to Havana

	Number per square yard		Pounds per acre	
Campeloma subsolidum	90.3		270.9	
Lioplax subcarinatus	19.0		22.8	
		230.6		887.6
Vivipara contectoides	118.0		590.0	
Pleurocera sp.	3.3		3.9	
Planorbis trivolvis	10.6		7.4	
Musculium transversum	26.3	38.5	13.1	21.6
Sphaerium stamineum	1.6		1.1	
Oligochaeta (small spp.)	6.6		0.2	
Leeches (small spp.)	36.1		6.1	
		81.0		10.5
Asellus sp.	25.0		2.4	
Chironomid larvae (small spp.)	13.3		1.8	
Total	350.1		919.7	

5. Havana to Lagrange Dam, 1915

16 Channel Collections, Aug. 2, 4, 5, 6, 27, 1915
Havana to Lagrange Dam (42.5 Miles)

	Number per square yard		Pounds per acre	
Campeloma subsolidum	5.0		15.0	
Lioplax subcarinatus	0.33		0.3	
Vivipara contectoides and subpurpurea	0.12	5.57	0.6	16.0
Pleurocera sp.	0.12		0.1	
Musculium transversum	6.0	6.0	3.0	3.0
Small oligochaetes	0.33		0.1	
Small leeches	1.0		1.7	
Asellus sp.	1.0		trace	
Hydropsyche larvae	1.2	3.77	0.2	3.0
Hexagenia bilineata (nymph)	0.12		1.0	
Chironomid larvae (small spp.)	0.12		trace	
Total	15.34		22.0	

22 Collections, 4- to 7-ft. Zone, Aug. 2, 5, 6, 27, 1915
Havana to Lagrange Dam (42.5 Miles)

	Number per square yard		Pounds per acre	
Campeloma subsolidum	48		144.0	
Lioplax subcarinatus	8		9.6	
Vivipara contectoides or subpurpurea	16	73	80.0	234.8
Pleurocera sp.	1		1.2	
Amnicola emarginata	4		0.1	
Musculium transversum	84	88	42.0	42.1
Small oligochaetes	9		0.3	
Small leeches	8		1.3	
Asellus sp.	1.5		0.1	
Hydropsyche larvae	7.6	31.1	1.5	5.7
Hexagenia, etc. (nymphs)	2.5		2.2	
Chironomid larvae (small spp.)	2.5		0.3	
Total	192.1		282.6	

20 Collections, 1- to 3-ft. Zone, Aug. 2, 5, 6, 1915
Havana to Lagrange Dam (42.5 Miles)

	Number per square yard		Pounds per acre	
Campeloma subsolidum	32.0		96.0	
Lioplax subcarinatus	2.3		2.7	
Vivipara contectoides or subpurpurea	55.0	99.3	275.0	385.7
Pleurocera sp.	10.0		12.0	
Amnicola sp.	2.0		0.1	
Musculium transversum	89.0	91.0	44.5	44.6
Small oligochaetes	trace			
Small leeches	5.5		0.9	
Asellus sp.	trace			
Hydropsyche larvae	4.0	18.3	0.8	5.2
Hexagenia, etc. (nymphs)	3.0		2.7	
Chironomid larvae (small spp.)	5.8		0.8	
Total	208.6		435.5	

2 Channel Collections, Aug. 6, 1915
Foot of Grand Island to Browning
(9-mile section of narrow, deep channel)

	Number per square yard		Pounds per acre	
Campeloma subsolidum	0.5	1.5	1.5	2.7
Pleurocera sp.	1.0		1.2	
Musculjum transversum	5.0	5.0	2.5	2.5
Chironomid larvae (small spp.)	1.0	6.0	trace	1.0
Hydropsyche larvae	5.0		1.0	
Total	12.5		6.2	

10 Collections, 4- to 7-ft. Zone, Aug. 6, 1915
Foot of Grand Island to Browning
(9-mile section of narrow, deep channel)

	Number per square yard		Pounds per acre	
Campeloma subsolidum	71.7	92.4	215.1	307.9
Lioplax subcarinatus	1.6		1.9	
Vivipara contectoides	14.9		74.5	
Vivipara subpurpurea	3.0		15.0	
Pleurocera sp.	1.2		1.4	
Musculium transversum	106.4	106.4	53.2	53.2
Chironomid larvae (small spp.)	1.9	10.3	0.2	4.5
Hydropsyche larvae	0.5		0.1	
Hexagenia, etc. (nymphs)	4.0		3.6	
Leeches (small spp.)	3.9		0.6	
Total	209.1		365.6	

4 Collections, 1- to 3-ft. Zone, Aug. 6, 1915
Foot of Grand Island to Browning
(9-mile section of narrow, deep channel)

	Number per square yard		Pounds per acre	
Campeloma subsolidum	46.2		138.6	
Lioplax subcarinatus	2.5	327.4	7.5	1516.0
Vivipara contectoides	272.5		1362.5	
Pleurocera sp.	6.2		7.4	
Musculium transversum	186.2	186.2	93.1	93.1
Hydropsyche larvae	3.7		0.7	
Chironomid larvae (small spp.)	3.7	26.1	0.5	4.3
Leeches (small spp.)	18.7		3.1	
Total	539.7		1613.4	

6. Lagrange Dam to Grafton

14 Collections (averaged), Aug. 11, 1915
Lagrange Dam to Florence

	Number per square yard		Pounds per acre	
Four channel collections	0.25		trace	
Two collections, 4- to 7- ft. zone				
Musculium transversum	115.		57.5	
Eight collections, 1- to 3-ft. zone				
Musculium transversum	15.6	16.3	7.8	9.2
Young Unionidae	0.7		1.4	
Small oligochaetes	1.2	2.2	trace	0.9
Hexagenia, etc. (nymphs)	1.0		0.9	
Total	18.5		10.1	

5 Channel Collections, Aug. 10, 1915
Valley City to Kampsville

	Number per square yard		Pounds per acre	
Vivipara subpurpurea	1.0	1.0	5.0	5.0
Musculium transversum	1.4	1.8	0.7	1.5
Young Unionidae	0.4		0.8	
Small oligochaetes	6.2	28.8	0.2	5.9
Planarians	2.0		trace	
Hydropsyche larvae	19.0		3.8	
Hexagenia, etc. (nymphs)	0.8		0.7	
Chironomid larvae (small spp.)	0.2		trace	
Perlid nymphs	0.2		0.2	
Gomphid nymphs	0.4		1.0	
Total	31.6		12.4	

17 Collections, 4- to 7-ft. Zone, Aug. 10, 1915
Valley City to Kampsville

	Number per square yard		Pounds per acre	
Campeloma subsolidum	0.2	0.2	0.6	0.6
Musculium transversum	12.6	14.6	6.3	10.3
Young Unionidae	2.0		4.0	
Small Oligochaeta	4.5	19.0	0.1	5.7
Small leeches	0.5		trace	
Planarians	1.0		trace	
Hydropsyche larvae	7.6		1.5	
Hexagenia, etc. (nymphs)	3.1		2.7	
Chironomid larvae (small spp.)	1.8		0.2	
Gomphid nymphs	0.5		1.2	
Total	33.8		16.6	

8 Collections, 1- to 3-ft. Zone, Aug. 10, 1915
Valley City to Kampsville

	Number per square yard		Pounds per acre	
Musculium transversum	4.8	4.8	2.4	2.4
Oligochaetes, small	3.0		0.1	
Hydropsyche larvae	2.2		0.4	
		11.4		5.1
Hexagenia, etc. (nymphs)	5.0		4.5	
Chironomid larvae (small spp.)	1.2		0.1	
Total	16.2		7.5	

7 Channel Collections, Aug. 12, 22, 23, 1915
Head of Diamond Island to Grafton

	Number per square yard		Pounds per acre	
Musculium transversum	2.0		1.0	
		2.8		2.6
Young Unionidae	0.8		1.6	
Chironomid larvae (small spp.)	0.4		trace	
Hexagenia, etc. (nymphs)	3.0		2.7	
Hydropsyche larvae	0.5	25.5	0.1	3.9
Gomphid nymphs	0.2		0.4	
Oligochaetes (small spp.)	21.4		0.7	
Total	28.3		6.5	

12 Collections, 4- to 7-ft. Zone, Aug. 12, 22, 23, 1915
Head of Diamond Island to Grafton

	Number per square yard		Pounds per acre	
Musculium transversum	4.4	5.7	2.2	4.8
Young Unionidae	1.3		2.6	
Chironomid larvae (small spp.)	1.4	11.3	0.2	5.5
Corethra larvae	0.5		trace	
Hexagenia, etc. (nymphs)	5.5		4.9	
Hydropsyche larvae	0.9		0.2	
Gomphid nymphs	0.1		0.1	
Oligochaetes (small spp.)	2.9		0.1	
Total	17.0		10.3	

12 Collections, 1- to 3-ft. Zone, Aug. 12, 22, 23, 1915
Head of Diamond Island to Grafton

	Number per square yard		Pounds per acre	
Campeloma subsolidum	0.1	0.1	0.3	0.3
Musculium transversum	6.3	7.9	3.1	6.3
Young Unionidae	1.6		3.2	
Chironomid larvae (small spp.)	1.6	29.3	0.2	21.3
Corethra larvae	0.7		trace	
Hexagenia, etc. (nymphs)	23.2		20.8	
Caddis larvae ("stick")	0.1		trace	
Gomphid nymphs	0.1		0.2	
Oligochaetes (small spp.)	3.2		0.1	
Leeches (small spp.)	0.4		trace	
Total	37.3		27.9	

II. Bottom Fauna of the Lakes of the Illinois Valley, Copperas Creek Dam to Lagrange, 1914—1915

1. Deeper, Bottom-Land Type (Clear-Mud, Liverpool, Thompson, Dogfish, Sangamon Bay)

Clear Lake, Sept. 1, 1915. Bottom Fauna
8 Collections, Depth, 8 to 8.5 ft. No Vegetation

	Number per square yard		Pounds per acre	
Campeloma subsolidum	1.2	3.9	3.6	17.1
Vivipara contectoides	2.7		13.5	
Musculium transversum	371.8	404.9	185.5	186.8
Pisidium sp.	33.1		1.3	
Leeches (small spp.)	16.0	37.7	2.7	11.7
Chironomid larvae (large spp.)	13.0		8.7	
Small Oligochaeta	8.7		0.3	
Total	446.5		215.6	

Clear-Mud Lake, Sept. 1, 1915. Bottom Fauna
12 Collections, Depth, 1 to 6 ft.
(Some vegetation at two shallow stations)

	Number per square yard		Pounds per acre	
Campeloma subsolidum	8.4	27.7	25.2	121.7
Vivipara contectoides	19.3		96.5	
Musculium transversum	219.1	249.2	109.5	110.7
Pisidum sp.	30.0		1.2	
Musculium jayanum	0.1		trace	
Leeches (small spp.)	42.1	58.7	7.1	17.7
Chironomid larvae (large spp.)	15.8		10.5	
Chironomid larvae (small spp.)	0.8		0.1	
Total	335.6		250.1	

LIVERPOOL LAKE, SEPT. 1, 1915. BOTTOM FAUNA
6 COLLECTIONS, DEPTH, 6.5 TO 9.5 FT. NO VEGETATION

	Number per square yard		Pounds per acre	
Campeloma subsolidum	2.6	5.9	7.8	24.3
Vivipara contectoides	3.3		16.5	
Musculium transversum	191.6	222.3	95.5	96.7
Pisidium sp.	29.1		1.1	
Valvata spp.	1.6		0.1	
Leeches (small spp.)	20.6	47.2	3.4	21.2
Chironomid larvae (large spp.)	26.6		17.8	
Total	275.4		142.2	

LIVERPOOL LAKE, SEPT. 1, 1915. BOTTOM FAUNA
9 COLLECTIONS, DEPTH 1.5 TO 6 FT.
(Some vegetation at shallower stations)

	Number per square yard		Pounds per acre	
Vivipara contectoides	23.4	23.4	117.0	117.0
Musculium transversum	6.6	26.5	3.3	4.2
Pisidium sp.	10.0		0.4	
Valvata spp.	2.2		0.1	
Amnicola limosa	5.5		0.3	
A. emarginata	2.2		0.1	
Leeches (small spp.)	15.5	53.7	2.6	28.2
Chironomid larvae (large spp.)	38.2		25.6	
Total	103.6		149.4	

THOMPSON LAKE, AUG. 12—20, 1914. BOTTOM FAUNA
8 COLLECTIONS,* DEPTH, 7 TO 9 FT.
(No vegetation; all mud bottom)

	Number per square yard		Pounds per acre	
Campeloma subsolidum	21.3		63.9	
Lioplax subcarinatus	10.5	31.8	12.6	76.5
Valvata spp.	470.6		25.8	
Musculium transversum	208.3	936.1	104.0	140.0
Pisidium sp.	257.2		10.2	
Small Oligochaeta	4.0		0.1	
Small leeches	23.5		3.9	
Chironomid larvae (large spp.)	123.7		82.4	
		212.0		94.2
Chironomid larvae (small spp.)	46.7		6.5	
Palpomyia larvae	3.1		0.2	
Caddis larvae	11.0		1.1	
Total	1179.9		310.7	

* All above "cut-road."

THOMPSON LAKE, AUG. 12—20, 1914. BOTTOM FAUNA
10 COLLECTIONS,* DEPTH, 1 TO 6 FT. NO VEGETATION
(Eight collections, mud bottom; two collections, sandy)

	Number per square yard		Pounds per acre	
Campeloma subsolidum	83.0		249.0	
Lioplax subcarinatus	63.0	218.5	75.6	687.1
Vivipara contectoides	72.5		362.5	
Amnicola limosa	40.0		2.2	
A. emarginata	31.0		1.1	
Valvata spp.	362.0	954.5	19.9	80.3
Musculium transversum	79.0		39.5	
Pisidium sp.	442.5		17.6	
Small Oligochaeta	10.0		0.3	
Small leeches	72.0		12.2	
		295.0		135.8
Chironomid larvae (large spp.)	180.0		120.0	
Caddis larvae	33.0		3.3	
Total	1468		903.2	

* All north of "cut-road."

THOMPSON LAKE, AUG. 12—20, 1914. BOTTOM FAUNA
12 COLLECTIONS,* DEPTH, 1 TO 6 FT. ALL IN VEGETATION
(Eleven collections, mud bottom; one collection, sandy)

	Number per square yard		Pounds per acre	
Campeloma subsolidum	28.7		86.1	
Lioplax subcarinatus	2.0	69.0	2.4	280.0
Vivipara contectoides	38.3		191.5	
Amnicola limosa	0.8		trace	
Valvata spp.	69.5		3.8	
		171.5		37.9
Musculium transversum	65.4		32.7	
Pisidium sp.	35.8		1.4	
Small leeches	9.5		1.6	
Planarians	2.5		trace	
Chironomid larvae (large spp.)	268.0		179.5	
		311.2		183.5
Chironomid larvae (small spp.)	2.5		0.3	
Caddis larvae	17.5		1.7	
Caenis nymphs	0.8		trace	
Hyalella knickerbockeri	10.4		0.4	
Total	551.7		501.4	

* All north of "cut-road."

THOMPSON LAKE,* AUG 12—20, 1914. BOTTOM FAUNA
4 COLLECTIONS, DEPTH, 2 TO 4 FT. ALL IN VEGETATION

	Number per square yard	Pounds per acre
Chironomid larvae (large spp.)	330	221.1
Small oligochaetes	30	1.1
Total	360	222.2

* Foot of lake, below "cut-road."

THOMPSON LAKE, AUG. 12—20, 1914. BOTTOM FAUNA
3 SAND-BOTTOM COLLECTIONS,* DEPTH, 1 TO 5 FT.
(Some vegetation)

	Number per square yard		Pounds per acre	
Campeloma subsolidum	46.6		139.8	
Lioplax subcarinatus	23.3	121.5	27.9	425.7
Vivipara contectoides	51.6		258.0	
Valvata spp.	96.6		5.3	
Musculium transversum	55.0	301.6	27.5	38.8
Pisidium sp.	150.0		6.0	
Chironomid larvae (large spp.)	10.0		6.7	
Small leeches	18.3		3.1	
Caddis larvae	26.6		2.6	
		103.1		22.4
Caenis nymphs	3.3		0.2	
Large libellulid (nymphs)	3.3		8.2	
Hyalella knickerbockeri	41.6		1.6	
Total	526.2		486.9	

* All above cut-road. These three collections, arranged separately here, are also included in tables preceding.

THOMPSON LAKE, AUG. 28, 1915. BOTTOM FAUNA
8 COLLECTIONS,* DEPTH, 7 TO 9 FT. NO VEGETATION

	Number per square yard		Pounds per acre	
Campeloma subsolidum	23.0		69.0	
Lioplax subcarinatus	11.2	100.5	13.4	413.9
Vivipara contectoides	66.3		331.5	
Valvata spp.	54.7		3.0	
Musculium transversum	106.5		53.2	
		372.7		64.6
M. jayanum	trace			
Pisidium sp.	211.5		8.4	
Small leeches	27.0		4.5	
Small Oligochaeta	1.2		trace	
		48.7		18.1
Chironomid larvae (large spp.)	20.3		13.6	
Caddis larvae	0.2		trace	
Total	521.9		496.6	

* All above "cut-road."

THOMPSON LAKE, AUG. 28, 1915. BOTTOM FAUNA
7 COLLECTIONS,* DEPTH, 1 TO 6 FT.
(No vegetation; all mud bottom)

	Number per square yard		Pounds per acre	
Campeloma subsolidum	32.7		98.1	
Lioplax subcarinatus	19.5	150.0	23.4	610.5
Vivipara contectoides	97.8		489.0	
Valvata spp.	43.5		2.3	
Musculium transversum	30.2		15.1	
		261.8		24.9
M. jayanum	trace			
Pisidium sp.	188.1		7.5	
Small leeches	19.5		3.3	
		32.9		12.2
Chironomid larvae (large spp.)	13.4		8.9	
Total	444.7		647.6	

* All above "cut-road."

THOMPSON LAKE, AUG. 28, 1915. BOTTOM FAUNA
7 COLLECTIONS,* DEPTH, 1 TO 6 FT. ALL IN VEGETATION
(Three collections, mud bottom; four collections, sand and mud)

	Number per square yard		Pounds per acre	
Campeloma subsolidum	39.1		117.0	
Lioplax subcarinatus	9.5	76.0	11.4	265.4
Vivipara contectoides	27.4		137.0	
Amnicola limosa	42.8		2.3	
Valvata spp.	109.2		6.0	
Musculium transversum	11.5	240.6	5.7	17.0
Musculium jayanum	trace			
Pisidium	77.1		3.0	
Chironomid larvae (large spp.)	11.7		7.8	
Caddis larvae	2.1		0.2	
		55.7		14.5
Small leeches	37.7		6.4	
Planarians	4.2		0.1	
Total	372.3		296.9	

* All above "cut-road."

THOMPSON LAKE,* AUG. 28, 1915. BOTTOM FAUNA
5 COLLECTIONS, DEPTH, 2 TO 6 FT. ALL IN VEGETATION

	Number per square yard	Pounds per acre
Vivipara contectoides	157	785.0
Pisidium sp.	12	0.4
Small leeches	169	28.7
Total	338	814.1

* Foot of lake, below "cut-road."

THOMPSON LAKE, AUG. 28, 1915. BOTTOM FAUNA
4 SAND-AND-MUD BOTTOM COLLECTIONS,* DEPTH, 1 TO 6 FT.
(All in vegetation)

	Number per square yard		Pounds per acre	
Campeloma subsolidum	31.5		94.5	
Vivipara contectoides	54.0	96.2	270.0	377.3
Lioplax subcarinatus	10.7		12.8	
Valvata spp.	118.7		6.5	
Amnicola limosa	50.0		2.7	
		243.9		14.6
Musculium transversum	5.2		2.6	
Pisidium sp.	70.0		2.8	
Small leeches	57.5		9.7	
Planarians	7.5		0.2	
		83.2		19.9
Chironomid larvae (large spp.)	14.5		9.7	
Caddis larvae	3.7		0.3	
Total	423.3		411.8	

* All above "cut-road." These four collections, averaged separately here, are also included in a preceding table.

Dogfish Lake, Aug. 18, 1914. Bottom Fauna
3 Collections, Depth, 6.5 to 7 ft. No Vegetation

	Number per square yard		Pounds per acre	
Vivipara contectoides	1.6	1.6	8.0	8.0
Musculium transversum	3.3		1.6	
Pisidium sp.	33.3	41.6	1.3	3.1
Valvata spp.	5.0		0.2	
Leeches (small spp.)	16.6		0.9	
		186.6		12.3
Chironomid larvae (large spp.)	170.0		11.4	
Total	229.8		23.4	

Dogfish Lake, Aug. 18, 1914. Bottom Fauna
5 Collections, Depth, 2 to 6 ft. All in Vegetation

	Number per square yard		Pounds per acre	
Vivipara contectoides	66.0		330.0	
		68.0		336.0
Campeloma subsolidum	2.0		6.0	
Musculium transversum	10.0		5.0	
Pisidium sp.	128.0		5.1	
Valvata spp.	160.0	302.0	8.8	19.1
Amnicola limosa	2.0		0.1	
Planorbis, small sp.	2.0		0.1	
Leeches (small spp.)	12.0		2.0	
Chironomid larvae (large spp.)	40.0		26.8	
Chironomid larvae (small spp.)	20.0	82.0	2.8	42.4
Small libellulid nymphs	2.0		10.0	
Caddis larvae	8.0		0.8	
Total	452.0		397.5	

Dogfish Lake, Aug. 31, 1915. Bottom Fauna
12 Collections, Depth, 7.5 to 8.5 ft. No Vegetation

	Number per square yard		Pounds per acre	
Vivipara contectoides	10.6		53.0	
Lioplax subcarinatus	5.0	18.3	6.0	67.1
Campeloma subsolidum	2.7		8.1	
Musculium transversum	10.5		5.2	
Pisidium sp.	74.5		2.9	
Valvata spp.	165.3		9.0	
		290.5		18.5
Amnicola emarginata	37.5		1.3	
Planorbis (small sp.)	1.6		0.1	
Physa (small sp.)	1.1		trace	
Leeches (small spp.)	38.8		6.5	
Chironomid larvae (large spp.)	88.0		58.9	
		155.0		66.4
Small Oligochaeta	11.6		0.4	
Hyalella knickerbockeri	16.6		0.6	
Total	463.8		152.0	

Dogfish Lake, Aug. 31, 1915. Bottom Fauna
3 Collections, Depth, 1 to 6 ft. Very Little Vegetation

	Number per square yard		Pounds per acre	
Pisidium sp.	33.3		1.3	
Valvata spp.	66.6	166.5	3.6	7.3
Amnicola emarginata	66.6		2.4	
Leeches (small spp.)	50.0		8.5	
Chironomid larvae (large spp.)	176.6	243.2	117.9	126.9
Small Oligochaeta	16.6		0.5	
Total	409.7		134.2	

SANGAMON BAY, SEPT. 8, 1915. BOTTOM FAUNA
8 COLLECTIONS, DEPTH, 6.5 TO 7.5 FT. NO VEGETATION

	Number per square yard		Pounds per acre	
Campeloma subsolidum	9.1		27.3	
Lioplax subcarinatus	13.7	24.3	16.4	51.2
Vivipara contectoides	1.5		7.5	
Musculium transversum	81.8		40.9	
		91.0		41.4
Valvata spp.	9.2		0.5	
Leeches (small spp.)	16.3		2.7	
Chironomid larvae (large spp.)	15.6		10.4	
		38.0		14.0
Caddis larvae	5.6		0.5	
Hexagenia nymphs	0.5		0.4	
Total	153.3		106.6	

SANGAMON BAY, SEPT. 8, 1915. BOTTOM FAUNA
4 COLLECTIONS, DEPTH, 1.5 TO 6 FT. NO VEGETATION

	Number per square yard		Pounds per acre	
Campeloma subsolidum	35.7		107.1	
Lioplax subcarinatus	12.7		15.2	
		54.9		145.3
Vivipara contectoides	4.0		20.0	
Pleurocera sp.	2.5		3.0	
Musculium transversum	217.5		108.7	
		232.5		109.5
Valvata spp.	15.0		0.8	
Leeches (small)	27.0		4.5	
Chironomid larvae (large spp.)	3.7		2.4	
Palpomyia larvae	0.7	45.4	trace	10.2
Caddis larvae	11.5		1.1	
Hexagenia, etc. (nymphs)	2.5		2.2	
Total	332.8		265.0	

2. Deep, Sand-Beach Type (Quiver, Matanzas)

Quiver Lake, Sept. 30 to October 12, 1914. Bottom Fauna
15 Collections, Depth, 7 to 12 ft. No Vegetation

	Number per square yard		Pounds per acre	
Campeloma subsolidum	58.2		174.6	
Lioplax subcarinatus	48.0		57.6	
Vivipara contectoides	462.0	745.5	2,310.0	2,754.6
Vivipara subpurpurea	trace			
Pleurocera sp.	177.3		212.4	
Amnicola emarginata	1.3			
Musculium jayanum	3.3		1.7	
Pisidium sp.	1.0	6.2	trace	2.9
Young Unionidae	0.6		1.2	
Chironomid larvae. (small spp.)	24.0		3.3	
Small leeches	52.6		8.9	
Large leeches	16.0		32.0	
Small Oligochaeta	54.0	161.1	1.8	47.5
Caddis larvae	2.6		0.2	
Agrionid nymph	0.6		0.3	
Asellus sp.	11.3		1.0	
Total	912.8		2,805.0	

QUIVER LAKE, SEPT. 30 TO OCTOBER 12, 1914. BOTTOM FAUNA
17 COLLECTIONS, DEPTH, 1 TO 6 FT.
(Most in vegetation)

	Number per square yard		Pounds per acre	
Campeloma subsolidum	24.7		74.1	
Lioplax subcarinatus	11.1		13.3	
		85.1		329.7
Vivipara contectoides	48.2		241.0	
Pleurocera sp.	1.1		1.3	
Amnicola emarginata	42.3		1.5	
Amnicola limosa	8.2		0.4	
Valvata spp.	9.4		0.5	
Physa, small	7.6	124.0	1.7	33.4
Young Unionidae	6.3		12.6	
Musculium transversum	32.0		16.0	
Pisidium sp.	18.2		0.7	
Chironomid larvae, large red	1.7		1.1	
Chironomid larvae, small	31.7		4.4	
Palpomyia larvae	5.5		0.3	
Caddis larvae	0.5		trace	
Hexagenia nymph	0.5		0.4	
Agrionid nymph	1.1	127.9	0.5	25.2
Large libellulid nymph	1.6		4.0	
Small leeches	34.1		5.7	
Large leeches	3.5		7.0	
Small Oligochaeta	11.7		0.4	
Hyalella knickerbockeri	36.0		1.4	
Total	337.0		388.3	

QUIVER LAKE, AUG. 30, 1915. BOTTOM FAUNA
3 COLLECTIONS,* DEPTH, 7 TO 10 FT. NO VEGETATION

	Number per square yard		Pounds per acre	
Vivipara contectoides	160	160	800	800
Small leeches	8.6		1.4	
Caddis larvae	6.0	26.2	0.6	3.1
Asellus sp.	11.6		1.1	
Total	186.2		803.1	

* All opposite Bishop's.

QUIVER LAKE, AUG. 30, 1915. BOTTOM FAUNA
14 COLLECTIONS, DEPTH, 1 TO 6 FT. MOST WITH VEGETATION

	Number per square yard		Pounds per acre	
Vivipara contectoides	7.1	7.1	35.5	35.5
Amnicola limosa	16.0		8.8	
		17.0		9.3
Musculium transversum	1.0		0.5	
Small leeches	11.9		2.0	
Chironomid larvae (large spp.)	162.8		109.0	
		190.3		113.9
Chironomid larvae (small spp.)	13.5		1.9	
Agrionid nymph	2.1		1.0	
Total	214.4		158.7	

MATANZAS LAKE, SEPT. 4, 1915. BOTTOM FAUNA
9 COLLECTIONS, DEPTH, 6.5 TO 8.5 FT. NO VEGETATION

	Number per square yard		Pounds per acre	
Musculium transversum	63.3		31.6	
Pisidium sp.	206.6	284.3	8.2	40.6
Valvata spp.	14.4		0.8	
Small Oligochaeta	4.4		0.1	
Small leeches	30.7		5.2	
		58.4		18.0
Chironomid larvae (large spp.)	18.6		12.4	
Palpomyia larvae	4.7		0.3	
Total	342.7		58.6	

MATANZAS LAKE, SEPT. 4, 1915. BOTTOM FAUNA
6 COLLECTIONS (IN CERATOPHYLLUM AND POTAMOGETON), DEPTH 2 TO 6 FT.
(Some vegetation at all stations)

	Number per square yard		Pounds per acre	
Campeloma subsolidum	5.0		15.0	
Pleurocera sp.	1.6	14.9	1.9	58.4
Vivipara contectoides	8.3		41.5	
Musculium transversum	15.0		7.5	
Pisidium sp.	48.3	66.6	1.9	9.6
Valvata spp.	3.3		0.2	
Leech, small	13.8		2.3	
Chironomid larvae (large spp.)	2.3		1.5	
		26.0		9.9
Hexagenia, etc. (nymphs)	6.6		5.9	
Caenis nymph	3.3		0.2	
Total	107.5		77.9	

3. SHALLOWER, WEEDY TYPE (FLAG, SEEDS, STEWART)

FLAG LAKE, OCT. 6, 1914. BOTTOM FAUNA
3 COLLECTIONS, DEPTH, 4 TO 5 FT. ALL IN VEGETATION

	Number per square yard		Pounds per acre	
Musculium transversum	6.6		3.3	
Pisidium sp.	93.3		3.7	
Valvata spp.	276.6	443.1	15.1	25.7
Amnicola limosa	20.0		1.1	
Physa, small sp.	46.6		2.5	
Leech, small sp.	33.3		5.6	
Chironomid larvae (large spp.)	33.3		22.1	
Chironomid larvae (small spp.)	110.0	186.5	15.4	45.2
Agrionid nymph	3.3		1.5	
Caddis larvae	6.6		0.6	
Total	629.6		70.9	

Flag Lake, Aug. 27—30, 1915. Bottom Fauna
15 Collections, Depth, 3.5 to 5 ft. Little Living Vegetation

	Number per square yard		Pounds per acre	
Vivipara contectoides	1.0	1.0	5.0	5.0
Leech, small	37.8		6.4	
Chironomid larvae (large spp.)	23.3	69.5	15.4	22.9
Chironomid larvae (small spp.)	8.4		1.1	
Total	70.5		27.9	

Seebs Lake, Oct. 13, 1914. Bottom Fauna
7 Collections, Depth, 2.5 to 5 ft. Some Vegetation

	Number per square yard		Pounds per acre	
Vivipara contectoides	2.8	2.8	14.0	14.0
Musculium transversum	8.5		4.2	
Pisidium sp.	57.1		2.3	
Valvata spp.	130.0		7.1	
		233.0		15.5
Amnicola limosa	27.5		1.5	
Amnicola emarginata	5.7		0.3	
Physa, small sp.	4.2		0.1	
Leeches (small spp.)	8.5		1.4	
Leeches (large spp.)	18.5		36.0	
Chironomid larvae (large spp.)	48.5		32.5	
Small Oligochaeta	480.0	702.5	16.8	94.5
Libellulid nymph (small sp.)	4.2		2.1	
Hyalella knickerbockeri	142.8		5.7	
Total	938.3		124.0	

Seebs Lake, Sept. 4, 1915. Bottom Fauna
8 Collections, Depth, 2 to 5.5 ft. Little Vegetation

	Number per square yard		Pounds per acre	
Vivipara contectoides	3.7	3.7	18.5	18.5
Valvata spp.	34.0	34.0	1.8	1.8
Leeches (small spp.)	24.2	26.5	4.1	5.6
Chironomid larvae (large spp.)	2.3		1.5	
Total	64.2		25.9	

Stewart Lake, Sept. 7, 1915. Bottom Fauna
12 Collections, Depth, 2 to 5.5 ft. All in Vegetation

	Number per square yard		Pounds per acre	
Campeloma subsolidum	8.7	20.8	26.1	41.0
Lioplax subcarinatus	12.0		14.4	
Vivipara contectoides	0.1		0.5	
Musculium transversum	21.0	69.8	10.5	24.4
Musculium jayanum	3.5		1.9	
Pisidium sp.	7.8		0.3	
Valvata spp.	32.5		1.7	
Young unionid	5.0		10.0	
Small Oligochaeta	2.5	54.0	0.1	8.4
Leeches, small	36.0		6.1	
Chironomid larvae (large spp.)	1.6		1.0	
Chironomid larvae (small spp.)	6.6		0.9	
Palpomyia larvae	4.0		0.2	
Hyalella knickerbockeri	3.3		0.1	
Total	144.6		73.8	

4. Very Shallow, very Weedy Type (Duck, Dennis, Crane)

Duck—Dennis Lake, Oct. 2, 1914. Bottom Fauna
5 Collections, Depth, 2.5 to 4 ft. All in Vegetation

	Number per square yard		Pounds per acre	
Valvata spp.	188.0		10.3	
Physa, small sp.	6.0		1.3	
Amnicola limosa	8.0	216	0.4	12.4
A. emarginata	12.0		0.4	
Pisidium sp.	2.0		trace	
Small leeches	2.0		0.3	
Small Oligochaeta	12.0		0.4	
Chironomid larvae (large spp.)	106.0		71.0	
Chironomid larvae (small spp.)	72.0		10.0	
		276		97.9
Agrionid nymph	6.0		3.0	
Libellulid nymph	4.0		10.0	
Corixa, small sp.	12.0		0.8	
Hyalella knickerbockeri	62.0		2.4	
Total	492		110.3	

Crane Lake, Sept. 7, 1915. Bottom Fauna
5 Collections, Depth, 1 to 3.5 ft. Some Vegetation

	Number per square yard		Pounds per acre	
Campeloma subsolidum	14.0	14.0	42.0	42.0
Musculium transversum	28.0		14.0	
		34.0		14.3
Valvata spp.	6.0		0.3	
Chironomid larvae (small spp.)	6.0		0.8	
Leeches (small spp.)	26.0		4.4	
Chironomid larvae (large spp.)	4.0		2.6	
		78.0		22.7
Palpomyia larvae	16.0		1.1	
Hexagenia, etc. (nymphs)	14.0		12.6	
Caddis larvae	12.0		1.2	
Total	126.0		79.0	

5. Dead Timber and Brush Areas

Dead Timber and Brush Areas, Vicinity of Havana,* Aug. 18 to Oct. 16, 1914
Bottom Fauna
6 Collections, Depth, 1.5 to 4 ft. Some Vegetation

	Number per square yard		Pounds per acre	
Campeloma subsolidum	1.6	6.6	4.8	29.8
Vivipara contectoides	5.0		25.0	
Amnicola emarginata	45.0	724.5	1.6	87.1
A. limosa	10.0		0.5	
Valvata spp.	531.6		29.2	
Physa, small sp.	6.6		1.5	
Planorbis trivolvis	1.6		1.1	
Planorbis, small sp.	3.3		trace	
Young Unionidae	1.6		3.2	
Musculium transversum	98.2		49.0	
Pisidium sp.	26.6		1.0	
Chironomid larvae (large spp.)	40.0	269.8	26.8	44.0
Chironomid larvae (small spp.)	61.6		8.6	
Palpomyia larvae	10.0		0.7	
Caddis larvae	3.3		0.3	
Small leeches	13.3		2.2	
Small Oligochaeta	5.0		trace	
Hyalella knickerbockeri	136.6		5.4	
Total	1,000.9		160.9	

* Head Quiver Lake; head Dogfish Lake; ridge between Flag and Thompson lakes.

Dead Timber and Brush Areas, Vicinity of Havana,* Aug. 31 to Sept. 11, 1915.
Bottom Fauna
10 Collections, Depth, 1.5 to 3.5 ft. Some Vegetation

	Number per square yard		Pounds per acre	
Vivipara contectoides	33.5	33.5	167.5	167.5
Valvata spp.	13.0	15.0	0.7	1.3
Small Planorbis sp.	1.0		0.1	
Musculium jayanum	1.0		0.5	
Chironomid larvae (large spp.)	41.0	78.0+	27.4	33.6+
Small leeches	37.0		6.2	
Hyalella knickerbockeri	present			
Total	126.5+		202.4+	

* Head of Clear Lake; head of Dogfish Lake; ridge between Quiver and Dogfish lakes; ridge between Flag and Thompson lakes.

III. Weed Fauna, 1- to 4-Foot Zone, Lakes and Backwaters in Vicinity of Havana, 1914

Dead Timber Ridge between Flag and Thompson Lakes, Oct. 6, 1914, Opposite "Warner's Cut," in Ceratophyllum and Algae
Weed Fauna, Upper 9 Inches (Depth, 2 ft.)

	No. per sq. yard	Pounds per acre	
Valvata spp.	22,500	1,347.5	
Amnicola limosa	4,500	209.0	
			2,164.0
Physa (small spp.)	1,500	82.5	
Planorbis trivolvis	750	525.0	
Chironomid larvae (small spp.)	750	52.5	
Pelocoris	270	256.5	429.0
Hyalella knickerbockeri	3,000	120.0	
Total	33,270	2,593.0	

Head of Flag Lake, Oct. 7, 1914, in Smartweed and Scirpus
Weed Fauna, Upper 9 Inches (Depth, 1.5 ft.)

	No. per sq. yard	Pounds per acre	
Physa (small spp.)	3,750	206.2	
Amnicola limosa	1,500	57.0	
			481.4
Valvata spp.	150	8.2	
Planorbis trivolvis	300	210.0	
Chironomid larvae (small spp.)	4,500	315.0	
Agrionid nymphs	1,500	750.0	
Small libellulid nymphs	750	375.0	2,036.2
Pelocoris femoratus	375	356.2	
Hyalella knickerbockeri	6,000	240.0	
Total	18,825	2,517.6	

MIDDLE OF DUCK LAKE, OCT. 2, 1914, IN POTAMOGETON PECTINATUS WEED FAUNA, UPPER 9 INCHES (DEPTH, 4 FT.)

	No. per sq. yard	Pounds per acre	
Valvata spp.	37,500	2,062.5	
Amnicola limosa	1,500	55.5	2,421.7
Planorbis trivolvis	375	262.5	
Physa (small spp.)	75	41.2	
Chironomid larvae (small spp.)	375	26.2	86.2
Hyalella knickerbockeri	1,500	60.0	
Total	41,325	2,507.9	

FOOT OF THOMPSON LAKE, WEST SIDE, AUG. 12, 1914, IN POTAMOGETON PECTINATUS WEED FAUNA, UPPER 9 INCHES (DEPTH, 3.5 FT.)

	No. per sq. yard	Pounds per acre	
Physa (small spp.)	9,600	528.0	534.6
Planorbis (small spp.)	120	6.6	
Caenis nymphs	1,920	153.6	
Agrionid nymphs	2,400	1,200.0	1,953.6
Chironomid larvae (small spp.)	6,000	420.0	
Hyalella knickerbockeri	4,500	180.0	
Total	24,540	2,488.2	

Foot of Thompson Lake, East Side, Aug. 14, 1914, in Ceratophyllum, Smartweed, and Algae
Weed Fauna, Upper 9 Inches (Depth, 2.5 ft.)

	No. per sq. yard	Pounds per acre	
Physa (small spp.)	6,000	335.0	
Planorbis (small spp.)	240	13.2	
Planorbis trivolvis	600	420.0	991.4
Valvata spp.	2,400	132.0	
Amnicola limosa	2,400	91.2	
Pelocoris femoratus	240	228.0	
Small libellulid nymphs	1,200	600.0	
Agrionid nymphs	600	300.0	
			1,314.0
Caenis sp. (nymphs)	1,200	96.0	
Small green chironomid larvae	600	42.0	
Hyalella knickerbockeri	1,200	48.0	
Total	16,680	2,305.4	

Middle of Flag Lake, Oct. 6, 1914, in Potamogeton, Ceratophyllum, and Algae
Weed Fauna, Upper 9 Inches (Depth, 4 ft.)

	No. per sq. yard	Pounds per acre	
Amnicola limosa	13,125	498.5	
Physa (small spp.)	750	41.2	560.3
Valvata spp.	375	20.6	
Small libellulid nymphs	375	187.5	
Agrionid nymphs	450	225.0	
			705.0
Chironomid larvae (small spp.)	750	52.5	
Hyalella knickerbockeri	6,000	240.0	
	21,825	1,265.3	

Foot of Thompson Lake, Middle, Aug. 14, 1914, in Potamogeton pectinatus Weed Fauna, Upper 9 Inches (Depth, 4.5 ft.)

	No. per sq. yard	Pounds per acre	
Amnicola limosa	6,000	228.0	
Physa (small spp.)	960	52.8	320.4
Valvata spp.	720	39.6	
Pelocoris femoratus	60	57.0	
Agrionid nymphs	480	240.0	
Çaenis sp., nymphs	480	38.4	833.4
Chironomid larvae (small spp.)	600	402.0	
Hyalella knickerbockeri	2,400	96.0	
	11,700	1,153.8	

IV. Bottom and Weed Fauna, Littoral Zone of Glacial Lakes of Northeastern Illinois, 1916

1. Bottom Fauna

Deep Lake, August—October, 1916. Bottom Fauna
7 Collections, Littoral Zone, 1 to 7 ft. Some Vegetation

	Number per square yard		Pounds per acre	
Pisidium spp.	100.5		4.0	
Amnicolidae	254.5		13.9	
Valvatidae	53.2	496.2	2.9	39.8
Physa	66.0		3.6	
Planorbis	22.0		15.4	
Leeches, small spp.	12.5		2.1	
Chironomid larvae (small spp.)	59.6		8.3	
Caenis nymphs	3.0		0.2	
Hexagenia, etc. (nymphs)	47.0		42.3	
Caddis larvae (on Chara)	56.5		5.6	
Sand-case caddis larvae	91.0		18.2	
		510.7		169.0
Libellulid nymphs	22.0		11.0	
Agrionid nymphs	28.1		14.0	
Gomphid nymphs	12.5		42.5	
Pelocoris femorata	19.3		18.3	
Hyalella knickerbockeri	156.2		6.2	
Asellus sp.	3.0		0.3	
Total	1,006.9		208.8	

CEDAR LAKE, AUGUST—OCTOBER, 1916. BOTTOM FAUNA
24 COLLECTIONS, LITTORAL ZONE, 1 TO 7 FT. SOME VEGETATION

	Number per square yard		Pounds per acre	
Sphaerium striatinum	4.4		3.0	
Musculium transversum	11.0		5.5	
Pisidium spp.	24.2		0.9	
Amnicolidae	37.4		2.0	
		121.0		24.2
Valvatidae	22.0		1.2	
Physa spp.	11.0		2.5	
Planorbis	6.6		0.3	
Unionidae, young	4.4		8.8	
Oligochaeta (small spp.)	4.4		0.1	
Chironomid larvae (small spp.)	46.2		[illegible]	
Palpomyia larvae	1.1		[illegible]	
Polycentropus larvae	trace			
Sand-case caddis larvae	26.4		5.2	
Caddis larvae (on Chara)	41.8		4.1	
Misc. caddis larvae	19.8		1.9	
		430.1		135.6
Hexagenia, etc. (nymphs)	85.8		77.2	
Agrionid nymphs	17.6		8.8	
Libellulid nymphs	15.4		16.5	
Gomphid nymphs	2.2		7.4	
Beetles, small	11.0		0.7	
Hyalella knickerbockeri	143.0		5.7	
Asellus sp.	15.4		1.5	
Total	551.1		159.8	

LAKE ZURICH, AUGUST—OCTOBER, 1916. BOTTOM FAUNA
13 COLLECTIONS, LITTORAL ZONE, 1 TO 7 FT. SOME VEGETATION

	Number per square yard		Pounds per acre	
Campeloma subsolidum	3.3	3.3	9.9	9.9
Pisidium spp.	21.3		0.8	
Amnicolidae	84.5	190.3	4.6	10.0
Valvatidae	84.5		4.6	
Oligochaeta (small spp.)	3.3		0.2	
Leeches (small spp.)	6.6		1.1	
Chironomid larvae (small spp.)	94.6		13.2	
Palpomyia larvae	6.6		0.5	
Corethra larvae	13.4		0.5	
Sand-case caddis larvae	38.7	226.6	7.7	49.2
Polycentropus larvae	1.5		0.3	
Agrionid nymphs	1.5		0.7	
Sialis larvae	1.5		0.9	
Hexagenia, etc. (nymphs)	25.3		22.8	
Hyalella knickerbockeri	33.6		1.3	
Total	420.2		69.1	

CRYSTAL LAKE, AUGUST—OCTOBER, 1916. BOTTOM FAUNA
6 COLLECTIONS, LITTORAL ZONE, 1 TO 7 FT. SOME VEGETATION

	Number per square yard		Pounds per acre	
Amnicolidae	58.5		3.2	
Valvatidae	58.5		3.2	
		168.0		16.0
Planorbis sp.	47.5		2.6	
Unionidae, young	3.5		7.0	
Chironomid larvae (small spp.)	3.5		0.5	
Ceratopogon larvae	3.5		0.2	
Hexagenia, etc. (nymphs)	11.0		9.9	
Libellulid nymphs	3.5		1.7	
Gomphid nymphs	3.5	340.0	11.9	40.4
Agrionid nymphs	3.5		1.7	
Caddis larvae (on Chara)	3.5		0.4	
Sand-case caddis	11.0		2.2	
Hyalella knickerbockeri	297.0		11.9	
Total	508.0		56.4	

LONG LAKE. AUGUST—OCTOBER, 1916. BOTTOM FAUNA
6 COLLECTIONS, LITTORAL ZONE, 1 TO 7 FT. SOME VEGETATION

	Number per square yard		Pounds per acre	
Sphaerium sp.	3.5	3.5	1.7	1.7
Chironomid larvae (small spp.)	36.5		5.1	
Hexagenia, etc. (nymphs)	11.0		9.9	
Sand-case caddis larvae	80.5		16.1	
Caddis larvae (on Chara)	22.0	190.0	2.2	50.7
Sialis larvae	7.2		4.3	
Gomphid nymphs	3.5		11.9	
Hyalella knickerbockeri	29.3		1.2	
Total	193.5		52.4	

SAND LAKE, AUGUST—OCTOBER, 1916. BOTTOM FAUNA
10 COLLECTIONS, LITTORAL ZONE, 1 TO 5 FT. SOME VEGETATION

	Number per square yard		Pounds per acre	
Amnicolidae	2.2	11.0	0.1	0.6
Valvatidae	8.8		0.5	
Oligochaeta (small spp.)	2.2		0.1	
Chironomid larvae (small spp.)	13.2		1.8	
Sand-case caddis larvae	13.2	33.0	2.6	13.1
Agrionid nymphs	2.2		1.1	
Gomphid nymphs	2.2		7.5	
Total	44.0		13.7	

PISTAKEE LAKE, AUGUST—OCTOBER, 1916. BOTTOM FAUNA
29 COLLECTIONS, LITTORAL ZONE, 1 TO 7 FT. SOME VEGETATION

	Number per square yard		Pounds per acre	
Goniobasis sp.	18.0	18.0	10.82	10.82
Sphaerium sp.	5.9		2.9	
Pisidium sp.	53.7		2.1	
Amnicolidae	260.9		14.3	
Valvatidae	38.5	366.2	2.1	26.0
Physa spp.	4.4		0.2	
Planorbis spp.	0.6		trace	
Unionidae, young	2.2		4.4	
Oligochaeta (small spp.)	5.3		0.2	
Planarians	13.6		0.5	
Small leeches	67.3		11.4	
Chironomid larvae (small spp.)	49.9		6.9	
Sand-case caddis	16.5		3.3	
		383.3		42.6
Hexagenia, etc. (nymphs)	9.0		8.1	
Agrionid nymphs	4.4		2.2	
Sialis larvae	2.2		1.3	
Asellus sp.	2.2		0.2	
Hyalella knickerbockeri	212.9		8.5	
Total	767.5		79.6	

Fox Lake (Including Mineola Bay), August—October, 1916. Bottom Fauna
28 Collections, Littoral Zone, 1 to 7 ft. Some Vegetation

	Number per square yard		Pounds per acre	
Campeloma subsolidum	0.8	0.8	2.3	2.3
Musculium transversum	0.8		0.4	
Musculium jayanum	1.6		0.8	
Sphaerium sp.	0.8		0.4	
Pisidium sp.	5.5	40.6	0.2	3.6
Amnicolidae	25.1		1.4	
Valvatidae	4.6		0.3	
Physa spp.	2.2		0.1	
Oligochaeta (small spp.)	15.6		0.5	
Planarians	1.6		0.1	
Leeches (small spp.)	14.7		2.5	
Leeches (large spp.)	0.8		1.5	
Chironomid larvae (small spp.)	9.2		1.3	
Palpomyia larvae	0.8		0.1	
Sialis larvae	0.8	278.2	0.5	18.0
Caenis larvae	7.7		0.6	
Caddis larvae, misc.	0.8		0.1	
Agrionid nymphs	3.1		1.5	
Libellulid nymphs	0.8		0.4	
Asellus sp.	0.8		0.1	
Hyalella knickerbockeri	221.5		8.8	
Total	319.6		23.9	

2. Weed Fauna

Head of Pistakee Lake, August 17, 1916, in Ceratophyllum Weed Fauna, Upper 9 Inches (Depth, 3.5 ft.)

	No. per sq. yard		Pounds per acre	
Amnicola limosa	1,440	1,920	54.7	81.1
Physa sp.	480		26.4	
Chironomid larvae (small spp.)	720	58,080	23.7	2,330.1
Small beetle	120		6.	
Plea striata	120		8.4	
Caddis sp. (basket case)	120		12.0	
Hyalella knickerbockeri	57,000		2,280.0	
	60,000		2,411.2	

North Side of Nippersink Lake, August 18, 1916, in Potamogeton and Ceratophyllum

Weed Fauna, Upper 9 Inches, (Depth, 3.5 ft.)

	No. per sq. yard		Pounds per acre	
Amnicola limosa	600	840	22.8	36.0
Physa spp.	240		13.2	
Chironomid larvae (small spp.)	2,880	22,080	95.0	863.0
Hyalella knickerbockeri	19,200		768.0	
Total	22,920		899.	

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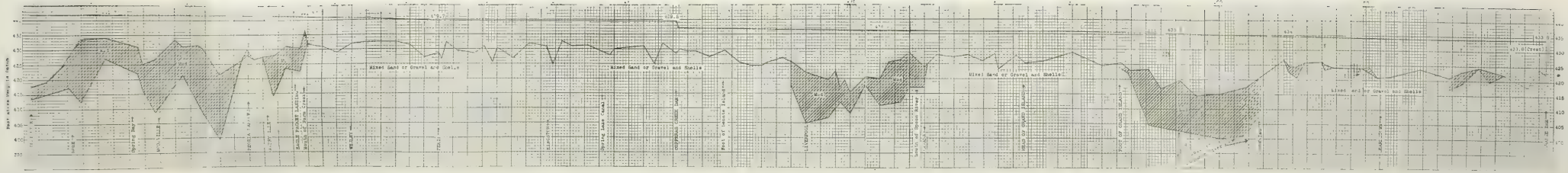
PROFILE OF A SECTION OF THE ILLINOIS RIVER

Profile of the Illinois River from Chillicothe to Lagrange dam, showing elevations of water surface at low gage of 1901, channel depths, and general character of upper layer of bottom soils and sediments. The profile marks out clearly the three deep, flat-sloped, mud-bottomed, natural pools in which the richest accumulations of small bottom-animals were found both in 1913 and 1915, viz.: the Peoria Lake pool, lying behind the great bar thrown up by Farm Creek; the Havana pool, behind the great natural wier formed by the wash from Spoon River; and the Sangamon pool, lying behind the high bar thrown up by the mouths of the Sangamon. The data here used (elevations, soundings, and borings) are from the report of the U. S. Engineers' Survey for a deep waterway, House Document No. 263, 59th Congress, 1st session, Washington, 1905.


Mixed Sand or Gravel and Shells
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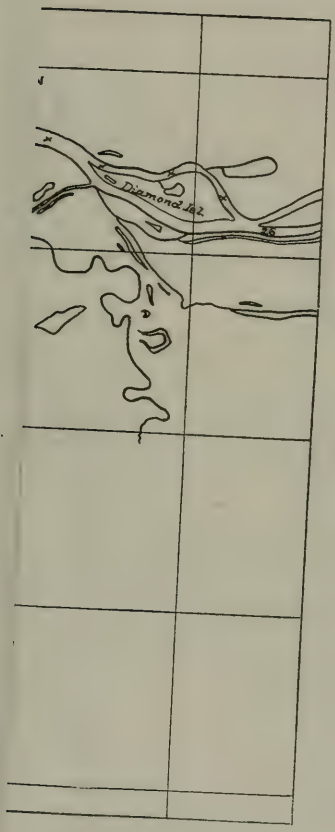
Spring Bay
Spring Lake Road
Port of Lewis Island
Lighthouse
Mouth of Spoon River
Port of Canoe Island
Mixed Sand or Gravel and Shells
Mixed Sand or Gravel and Shells
Mixed Sand or Gravel and Shells

INDEX SHEET to the following maps of Illinois River and bottom-land lakes, Chillicothe to Grafton. (After U. S. Engineers' Survey, 1902–1905, House Doc. 263, 59th Congr., 1st Session, 1905.)



† For non-technical summary, see page [illegible].

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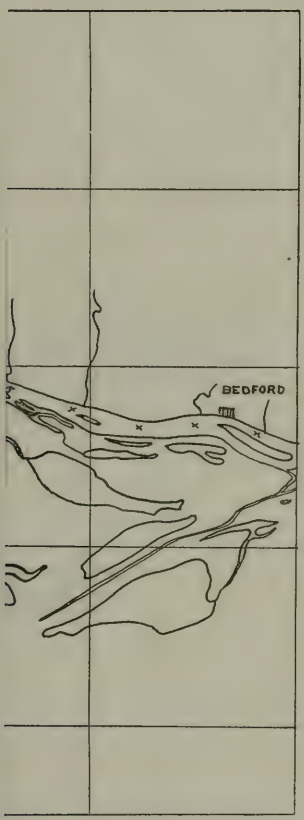

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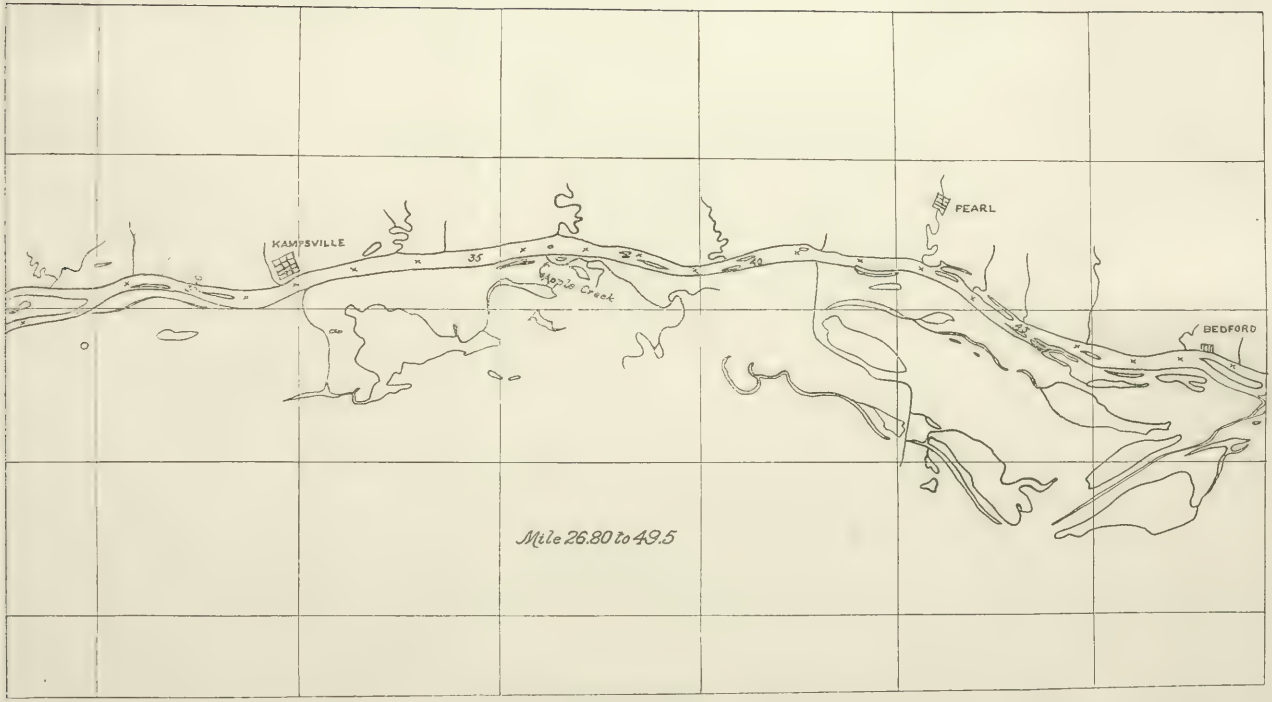

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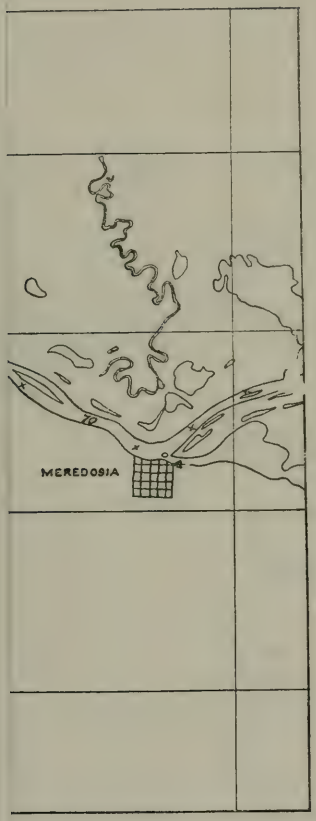

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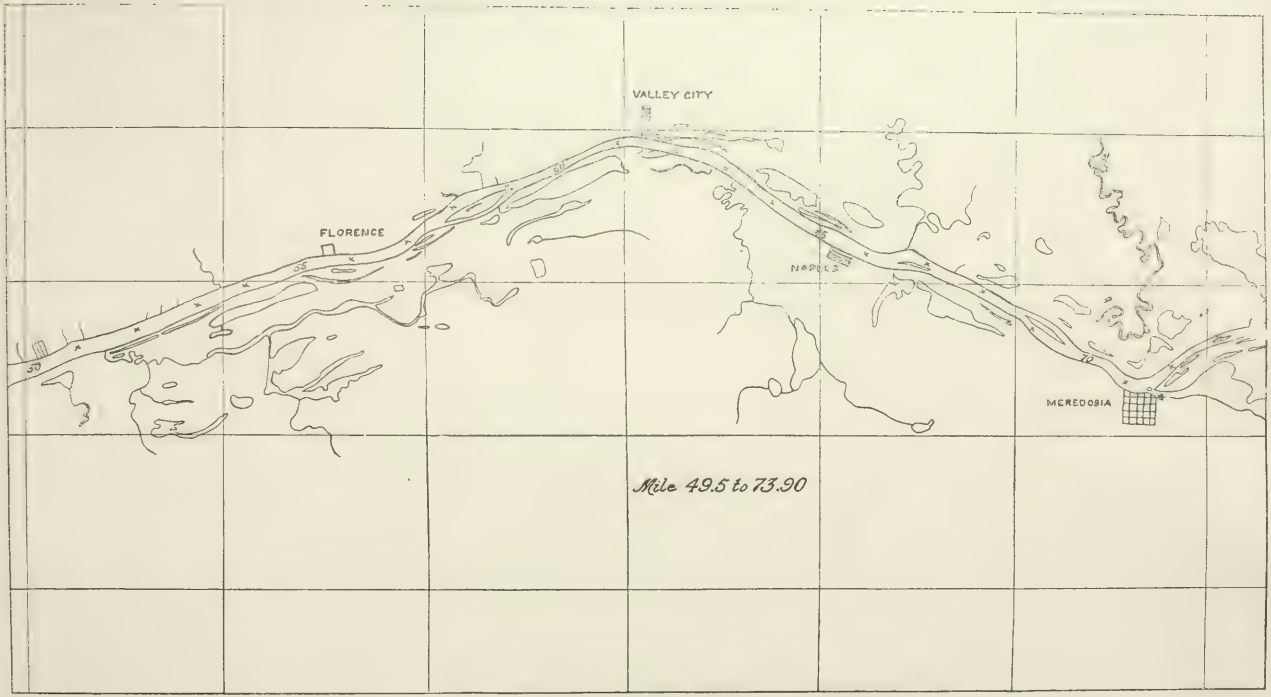

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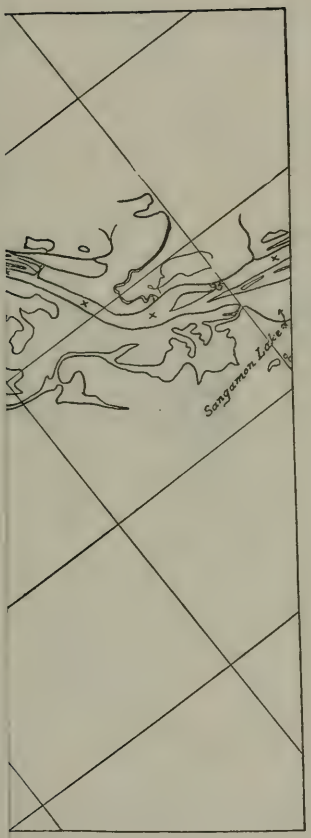

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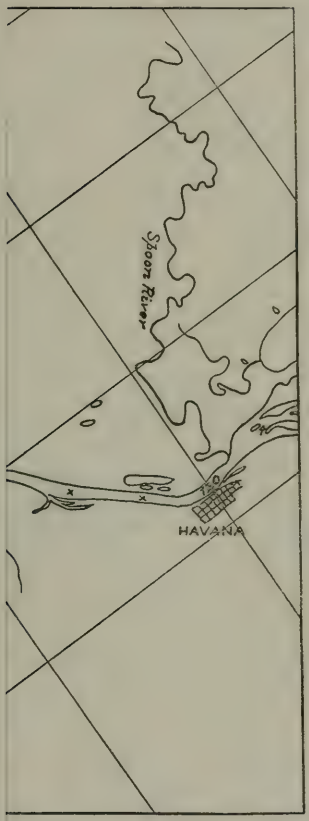

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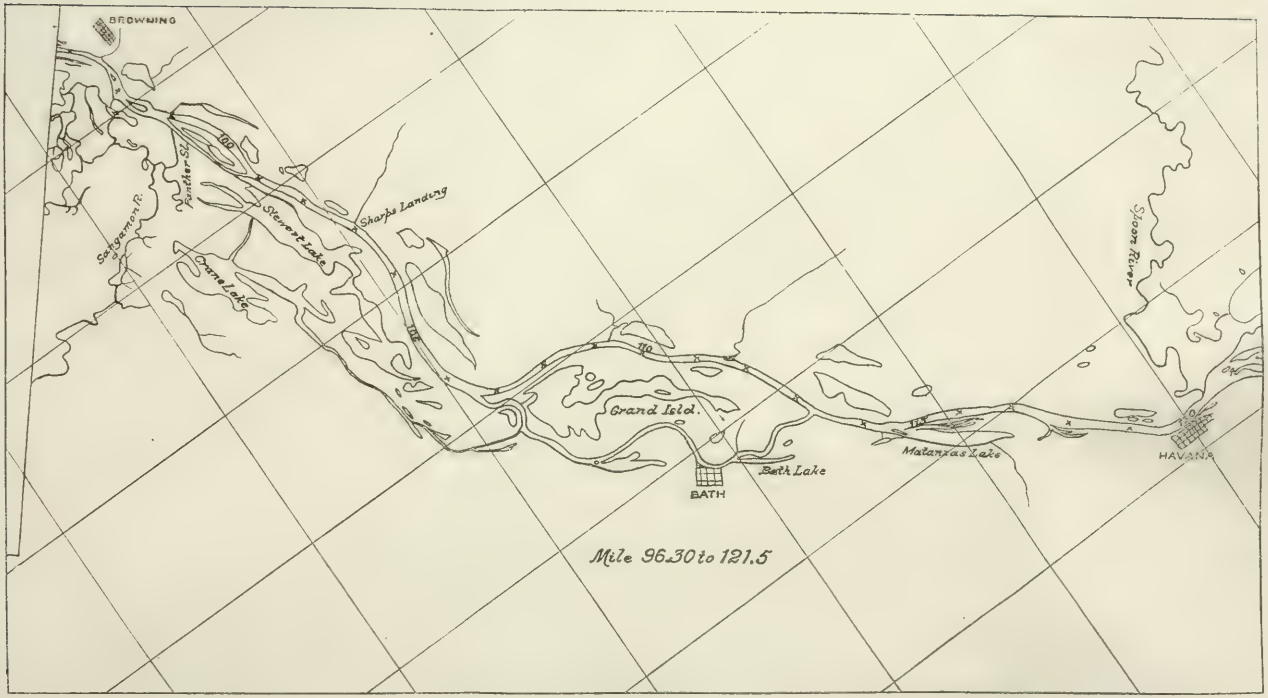

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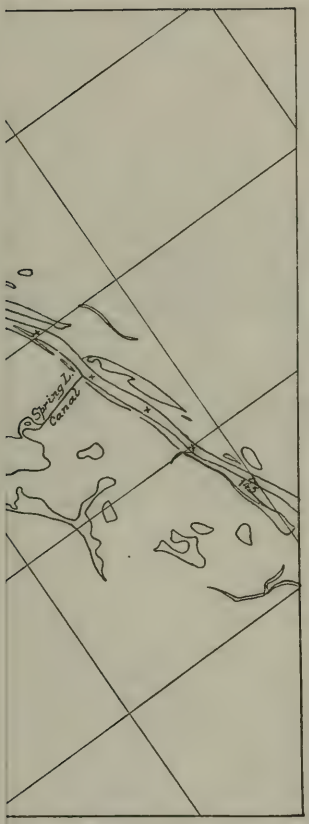

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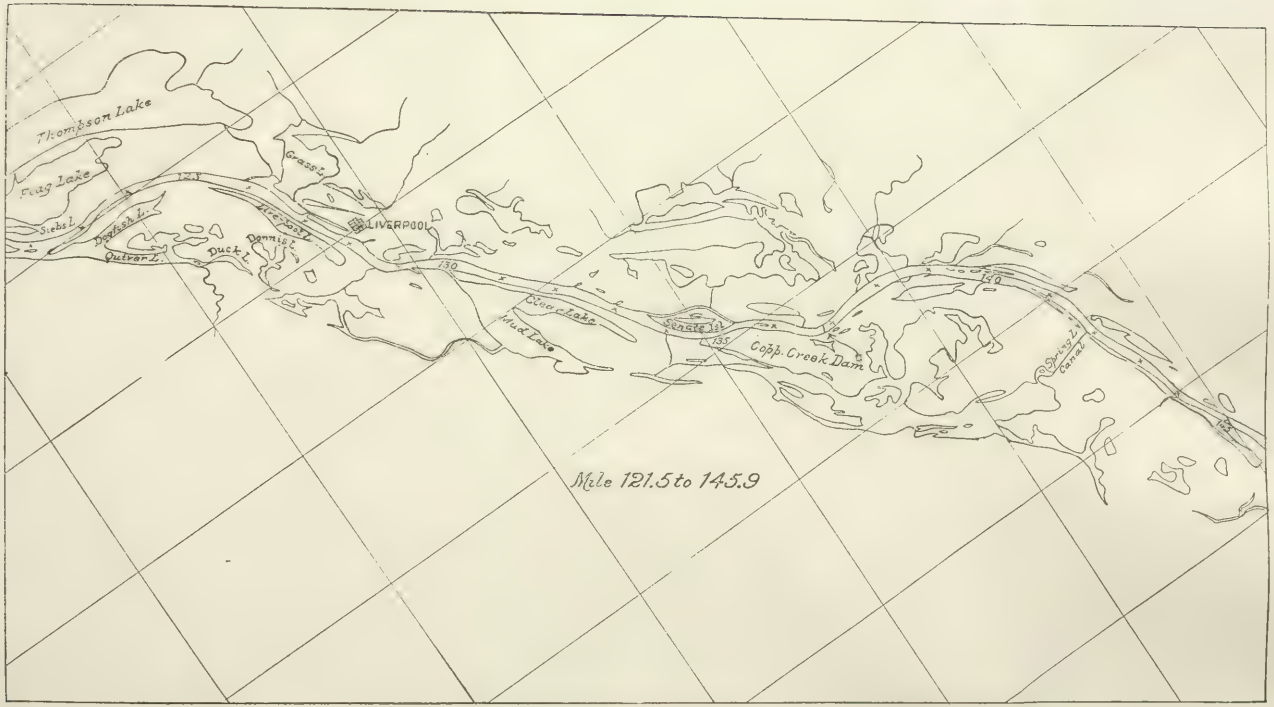

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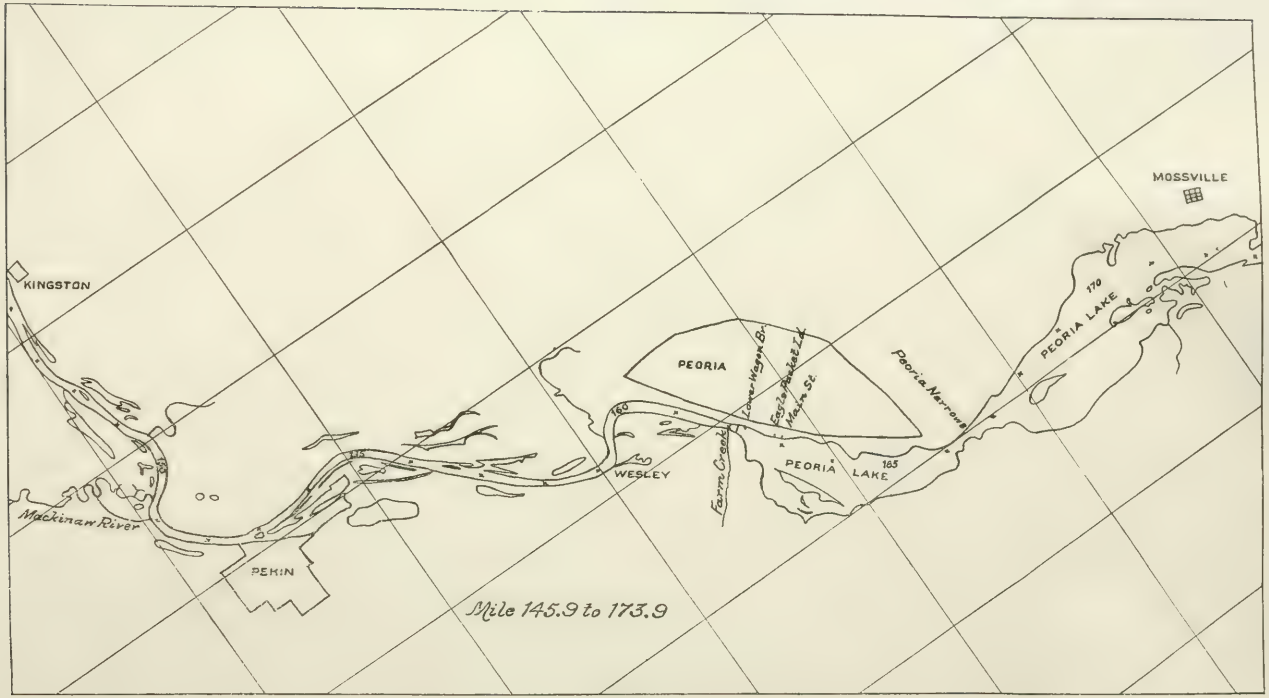

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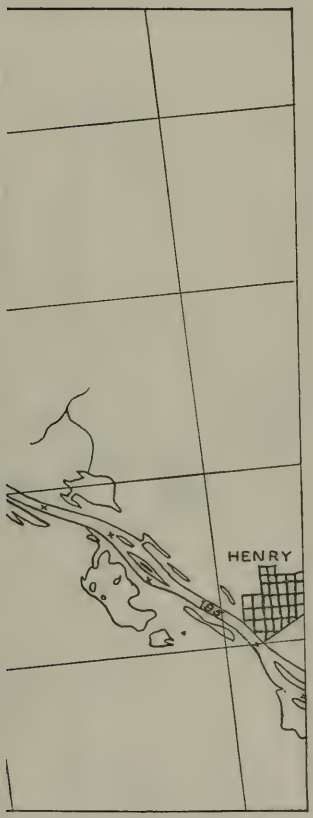
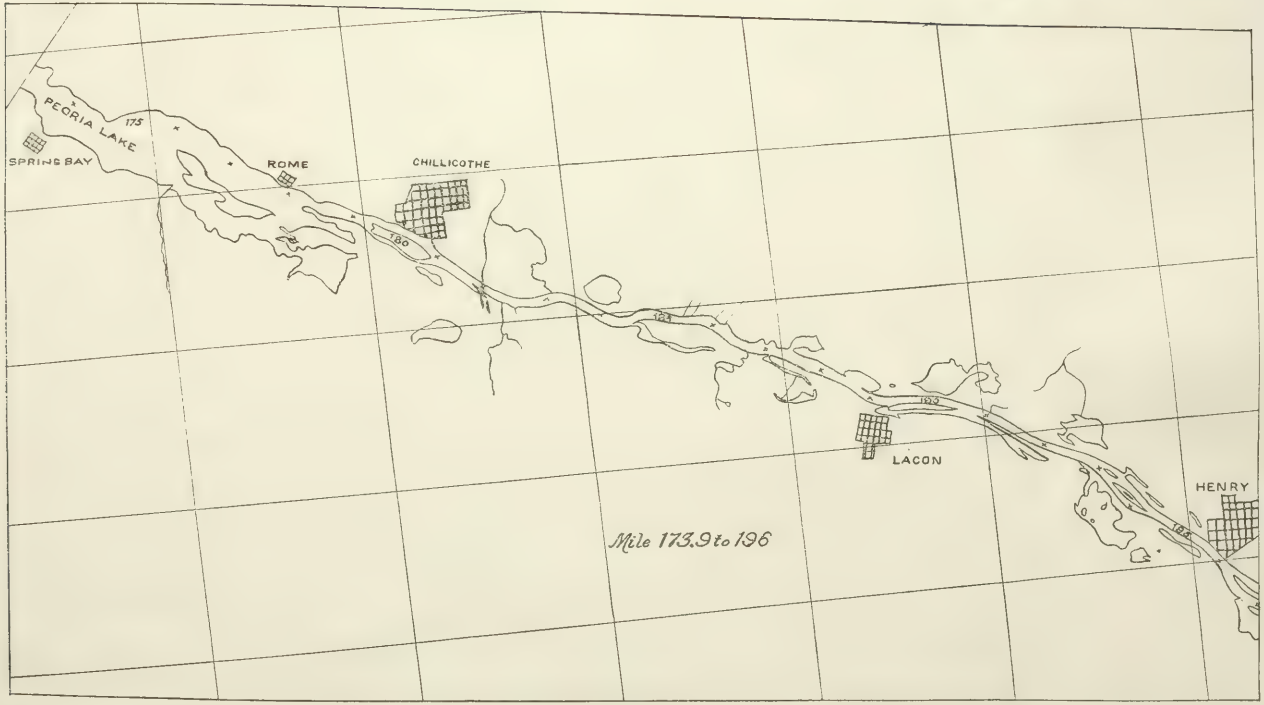


† For non-technical summary, see page 300.



8. Chillicothe sheet.

ARTICLE XVI.—*An Ecological Survey of the Prairie Vegetation of Illinois.** BY HOMER C. SAMPSON.

INTRODUCTION †

The purpose of this survey was to determine as far as possible the composition and ecological relation of the prairie vegetation of Illinois. The prairie area of this state is an eastern arm of the prairie region proper which forms a distinct formation between the grass-lands of the Great Plains on the west and the deciduous hardwood forest on the east. While the origin of this prairie dates back to the changes in climate following the uplift of the Rocky Mountains and subsequent changes during and following the glacial period, the factors limiting its present distribution are to be found in the present climatic and edaphic conditions together with the biotic factors which affect succession from prairie to forest associations.

The occurrence of all the great prairie regions of the world in temperate climates indicates that temperature plays a rôle, either directly or indirectly, in determining the general boundaries of distribution of the prairies. For the prairie under consideration, Transeau's map (26), comparing the ratios of rainfall to evaporation from a free water surface in the three great vegetational areas noted above, shows rather clearly that definite ratios of these two important climatic factors, with which temperature is indirectly involved, coincide closely with the present limits of distribution. The western boundary of the prairie is marked by a rainfall equal to about 60 per cent. of the evaporation from a free water surface, while on the eastern boundary of the prairie the ratio of rainfall to evaporation is about 80 per cent. Similarly the rainfall-evaporation ratios marking the boundaries of the Great Plains are 20 and 60 per cent., while those of the eastern forest range from 80 to 130 per cent. The prairie therefore lies in a region in which the ratio of rainfall to evaporation ranges from 60 to 80 per cent. (See map on next page.)

The presence of local areas of forest together with man's ability to carry on silviculture throughout the greater part of this range is sufficient evidence that the occurrence of prairie vegetation is not limited by climate alone. Edaphic factors and the difficulty with which a forest vegetation invades and succeeds that of the prairie must also be taken into account. As the complex of climatic factors approaches the limiting conditions for forest development, the weight of the edaphic factors be-

* Papers from the Department of Botany, Ohio State University, No. 126.
† For non-technical summary, see page 569.

comes more and more evident and may tip the balance either in favor of forest or of prairie. Similar conditions exist between prairie and plains vegetation on the western edge of the prairie. But as we approach the center of the prairie region edaphic factors become less prominent, and it is here that we find prairie on the greatest number of edaphic habitats.

Transeau (25,26) was the first to point out the characteristics of the centers of distribution of the vegetation of bogs and forests of North

Map showing ratio of rainfall to evaporation expressed in percentages. (After Transeau.)

America and to call attention to the meaning and use of the term "center of distribution". As he used it the term does not imply that the plants have necessarily spread from the present centers, but that the complex of climatic factors most favorable to the development of the type of vegetation characteristic of each center is localized there, and that as we depart from such centers we find conditions more and more unfavorable and resulting in the elimination of such species as are most rigidly

dependent upon climatic conditions. He also showed that the species comprising the vegetation of any center are more abundant, attain a greater size, and have a wider range of habitats within the limits of the center of distribution than elsewhere. These same conditions apply to the prairie. In addition to the climatic, edaphic, and biotic factors mentioned above, prairie fires are also important locally and have been variously emphasized from time to time.*

To sum up, climatic factors are important in determining the general boundaries of distribution of the prairie, while edaphic factors are important in determining the origin and character of the prairie associations within these boundaries. The edaphic factors become more and more prominent toward the edges of the prairie, as in eastern Illinois. When a prairie association is once established, biotic factors and prairie fires are important in checking invasion by forest vegetation.

The location of Illinois at the eastern boundary of the prairie makes it a region of considerably more than local ecological interest. As a prairie state it has awakened interest since the time of the first settlers, several of whom have recorded brief but glowing descriptions of the early prairies. Of these older descriptions, one of the most important was written in 1857 by Frederic Gerhard (7), who greatly enriched his publication by appending a forest and prairie map of the state compiled by Dr. Frederick Brendel of Peoria. This map shows the relative distribution of prairie and forest at that time, and a reproduction of it by Barrows (1) is included in the present article (page 526).

Unfortunately these pioneer writers, accustomed to life in a forested region, were generally unfamiliar with the plants of the prairie and failed to leave us an adequate account of the natural prairie flora. Furthermore, the importance of a knowledge of the relationship of plants to the environment in which they live was not recognized until a later date. Indeed the dynamic and genetic relationship of plant associations was not fully appreciated until Cowles (4) pointed out its significance in 1899. As a result of this belated appearance of modern ecological conceptions the earlier accounts of the prairie are notably lacking in a record of the different associations of prairie plants and of their composition and successional relationships. The published accounts deal chiefly with associations on the broken soil of slopes or with those along forest borders conspicuous for their great display of coarse herbs, and leave the erroneous impression that the original prairie flora was a mixture of a great variety of species. This impression, however, is offset by the occasional and significant reference to the prairie as a "sea of grasses" and by the statement of C. W. Short in 1845 that "Its leading feature is rather the unbounded profusion with which a few species occur in certain localities than the mixed variety of different species occurring everywhere".

* For an historical résumé of the theories of the prairie see Shimek (24), "The Prairies."

Original Prairie and Forest Area in Illinois
(After Brendel and Barrows)

Cowles (4, 5) has shown that the plant associations and their successions in a given region are correlated with its physiographic development. In order therefore to determine the original prairie associations the only feasible point of attack lies in a detailed study of the relic associations still to be found in the various physiographic habitats of the state. The conditions in these relic associations where least disturbed by man approximate closely the conditions which existed in the much more extensive association of only a little more than half a century ago. The order of succession of the associations is without doubt the same today as in the past, and the composition of the undisturbed associations fairly representative. Some of the swamp prairies and many of the sand prairies of the state have already been studied on this basis by Cowles (5), Sherff (23), Gleason (9, 10), Gates (6), and Vestal (27, 28). The present investigation was also carried out on this basis with special reference to primitive conditions and an attempt to include practically all the prairie habitats of the state. The main contribution of this report is the attempt to determine and classify the associations of prairie vegetation in Illinois and point out the successions between them. The field work was entirely observational, but experimental data of other workers have been drawn upon wherever they appear to have a direct bearing upon the topic under discussion. Quantitative experimental data on the physiological factors underlying the problems of the prairie associations and their successions are too meager at present for a full discussion of the underlying causes. A more definite knowledge of both the ecological anatomy and physiology of many of the plants concerned will have to be obtained before some of the more fundamental questions can be answered.

Most of the investigations were made during the summers of 1915 and 1916 with the cooperation of the Illinois State Laboratory of Natural History, through its director, Professor Stephen A. Forbes, and under the direction of Dr. H. C. Cowles and Dr. George D. Fuller, of the University of Chicago. This report also contains many data obtained previous to the above dates and from observations made in many sections of the state during the summers of 1917 and 1918. I am particularly indebted to Professor Forbes for his cooperation in the survey and for the aid he has given in the illustration of the report. I wish also to express many obligations to Dr. Edgar N. Transeau, of the Ohio State University, who first introduced me to the problems of the prairie in the summer of 1910, and helped me with valuable data and criticisms during the preparation of this report. To Dr. A. E. Waller, of the Ohio State University, I am indebted for criticisms and suggestions on the final report.

Location of Existing Virgin Prairies of the State

The location of most of the prairies studied was obtained by means of circular letters of inquiry sent to each of the county surveyors of the

state. Seventy-three of a possible 102 replies were received. The following tabulation by counties is taken directly from the letters received. It should be noted that these reports are not exhaustive, as no surveyor would be expected to have a complete list of all the undisturbed areas of his county. In some cases more definite statements are desirable, but the ones given are included with the hope that they may be of value to other workers in the field. Unfortunately, grazing was not suggested as a type of disturbance in the letters of inquiry, and some of the areas here reported have been pastured and are now generally blue-grass pastures. Where this fact is known it has been added by the writer. Asterisks refer to regions investigated in this survey.

Adams. Lowlands along the Mississippi River extending through three townships north of Quincy.

Bond. A few small tracts in addition to numerous roadsides.

**Bureau.* Several thousand acres of sand and swamp prairie along Green River. Mostly pastured.

**Carroll.* Several thousand acres of sand prairie and flood-plain prairie south of Savanna. Most of the sand prairie and some of the flood-plain prairie has been pastured.

**Cook.* About 5,000 acres on the old lake bed of Lake Chicago and a few small tracts on the Valparaiso moraine. There are 2,000 acres in the vicinity of Ashburn within the city limits of Chicago.

**Crawford.* One hundred and sixty acres two and one-half miles northwest of Porterville. Pastured.

De Kalb. About four acres near Maple Park. R. E. Wagner.

Dupage. Small areas along east branch of Dupage River between Swift and Lisle.

**Effingham.* A few small tracts and roadsides. An 80-acre tract of Andropogon prairie on the farm of David Woods, 9 miles southwest of Dietrich, was reported to the writer in 1918. Forty acres of this tract reported plowed in 1917.

Fulton. Lowlands along the Illinois River.

**Grundy.* "Hay swamps" north of Coal City; 220 acres 5 miles west of Morris along the Illinois River. Mostly flood-plain; some moraine and mostly pastured.

Hancock. Flood-plain along Mississippi River south of Warsaw.

**Henry.* Sand and swamp land in northern part of county. Mostly pastured.

**Jasper.* Forty acres southwest of Gila and 320 acres 3 miles east of West Liberty. Pastured. Burke's prairie of 2 acres two miles southwest of Wheeler. Virgin. A small area northwest of Wheeler now under cultivation.

**Jo Daviess.* Some prairie in north and southwest part. Pastured.

Madison. Wet prairie in Shonteau township.

**Marshall.* Saratoga Lake region one mile north of Camp Grove. Another small area 6 miles east of Lacon. Mostly swamp, some upland prairie.

Mercer. Flood-plain along the Mississippi River.

Ogle. Small tract one mile east of Polo. W. E. Eikenberry.

Peoria. Lowlands along the Illinois River.

Randolph. Flood-plain along Mississippi and Kaskaskia rivers.

**Richland.* Fox Prairie, 5 miles west of Olney. Cemetery at Noble.

Rock Island. Flood-plain along Mississippi River.

Washington. Flood-plain along Kaskaskia River.

White. Small tracts in Enfield and Hawthorn townships.

Whiteside. Prairie between Albany and Erie.

Winnebago. Small tracts along Rock River.

All of the above counties and the remaining counties with the exception of those in the southernmost part of the state were reported to have patches of virgin prairie along railway rights-of-way, old line-fences, and roadways. Owing to a difference in farming methods these latter relics are somewhat more abundant in the southern half of the state than elsewhere. Numerous relics along most of the principal railways of the state and along hundreds of old line-fences were seen during the survey.

This brief summary of present conditions shows that there are still several thousand acres of virgin prairie in the state which have been so little disturbed by man that they are of considerable value for ecological studies. The data also show that the greater area of these relic tracts are on flood-plains, swampy regions, and sand. Outside of the sand prairie the upland prairies are limited to small tracts, fence-rows, and railway rights-of-way, the latter of which were considered only after the survey had advanced sufficiently to indicate their limitations.

Origin of the Prairie Habitats

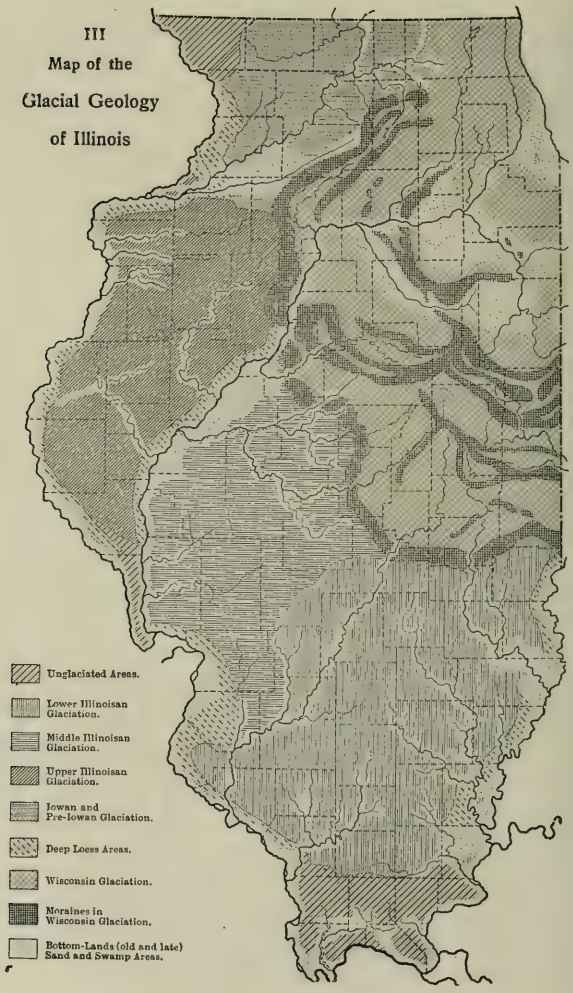
The various plant habitats of the state are correlated with its recent geological history. The accompanying glacial and soil map after Leverett (18) and Hopkins (15) shows that nearly all of the state has been glaciated. The glaciers left the state with a gently rolling topography. The depressions, resulting from the formation of moraines across preglacial valleys and the unequal deposition of the glacial drift, became postglacial lakes and sloughs which were slowly drained. In general the moraines became forested, but many of the lakes and sloughs through gradual filling and draining became prairies, a process which was far from complete when the farmer entered the state and established artificial drainage systems. The extensive areas and long duration of the wilderness of sloughs and swamps in the Wisconsin glaciation is best attested today by the depth and extent of the rich humus soil that accumulated in them. Their estimated dimensions are not lessened by the stories of the early settlers who swam their horses across them in early

III

Map of the

Glacial Geology

of Illinois



spring or skated for many miles across country in winter with but short walks between the swamps. Artificial drainage has not only reduced the swamps, but it has also caused a general lowering of the water-table, so that wells in this region must now be dug 5–10 feet deeper than formerly. A few of these undrained morainal depressions surrounded by definite zones of native vegetation remain today, but most of them have been disturbed by grazing and mowing. The swamp prairies of the Chicago plain with their intervening lines of beaches may be included in this group.

Postglacial drainage at first favorable for prairie formation through the drainage of swamps ultimately became destructive through erosion of the soil in the development of the natural drainage systems. The invading heads of the ravines destroying the prairie turf were usually accompanied by the development of a forest vegetation. This fact is strikingly illustrated in Brendel's map, which shows a fringe of forest along all the principal water courses. These belts of forest are much narrower and the intervening prairies much larger on the youthful topography of the Wisconsin glaciation than on the older Illinoisan glaciation. This condition is a result partly of the difference in age of the drainage systems of the two regions and also of the greater amount of forest encroachment on the pre-erosion areas of the prairie in the southern Illinoisan glaciation. Flood-plain formation has resulted in both forest and prairie; the prairies arising from the lagoons and swampy regions have much in common with those arising from morainal depressions. Outwash from the Wisconsin glaciers gave rise to enormous sand areas and sand dunes in the northern half of the state, some of which were forested, the remainder being covered with a prairie vegetation and plants of the Great Plains. Rock outcrops and eroding clay bluffs were generally forested, but the slopes of lower gradient were frequently covered with a xerophytic prairie flora. Local areas of this type are still to be found in the vicinity of forest borders, though many of them must be regarded as secondary successions following deforestation.

In addition to the prairies arising from postglacial lakes and subsequent erosion, there is some evidence that the sand prairies and some of the upland prairie region of the state date back to an arid postglacial period during which there was an eastward extension of the prairie and plains flora. The conifer zone following the retreat of the glacier is thought to have been succeeded immediately by a xerophytic prairie flora extending as far eastward as Ohio. Subsequent increase in humidity in the Mississippi valley was then followed by a westward migration of a more mesophytic prairie flora and the deciduous forest of the east which have their present tension zone in Illinois. As evidence of this view Gleason (8) calls attention to the presence of scattered colonies of prairie species beyond the eastern limit of the present prairie province and to the isolated occurrence of such western plants as *Cristatella*

Jamesii, Lesquerella, argentea, and *Opuntia fragilis* on the sand dunes of Illinois many miles from their nearest reported station in the west.

This brief summary of the prairie habitats of the state emphasizes the fact that the chief prairie region reached its greatest development on postglacial pre-erosion topography. The associations of prairie plants found in these habitats may be placed in two distinct groups: the hydrarch successions found on flood-plains, in morainal depressions, and on the old lake bed of Lake Chicago; and the xerarch successions found on sand and xerophytic upland glacial soils.

Succession of Prairie Plant Associations

1. the hydrarch successions

The Succession (a) on the River Flood-plains

The largest and least disturbed example of this type of prairie studied is located on the flood-plain of the Mississippi River south of Savanna. The exact area of this prairie was not determined, but it is known to include several thousand acres. The associations of prairie plants found on this flood-plain are usually distinct and readily differentiated. The list of associations found and their successional relations are represented diagramatically in Figure 1. See also Plates XLVIII—LIII for illustrations of the individual associations, and pages 558—568 for a list of representative species.

The associations in the diagram are given in order from swamp to prairie. On these Savanna prairies the plants representing the various associations usually occupy from 85 to 95 per cent. of the area of the association which they represent and are in every case the dominant plants of their respective associations. The areas of the individual associations vary from a few square rods to tens of acres. Where the slope gradient is steep they occur as narrow strips of only a few feet in width and some of them may be eliminated entirely. One *Panicum virgatum* association was found occupying nearly a hundred acres (Plate LII), and similar areas of *Spartina Michauxiana* are not infrequent. *Andropogon furcatus* is the dominant grass of the drier portions of the flood-plain, but owing to the fact that habitats which have reached this stage of development are suitable for agriculture very few such areas remain undisturbed.

Some of this prairie is now being grazed and is losing its natural aspect. Hundreds of acres, however, are disturbed only by late autumn mowing and occasional fires, while occasional local areas may be found that are seldom disturbed by man. It is in these least disturbed tracts where the dead grass remains from year to year that the dominant plants maintain their purest stand. The secondary species become insignificant, being represented only as scattered individuals here and there throughout the association. It is in such situations also that the transition zones between the various associations are most clearly defined and readily recognized.

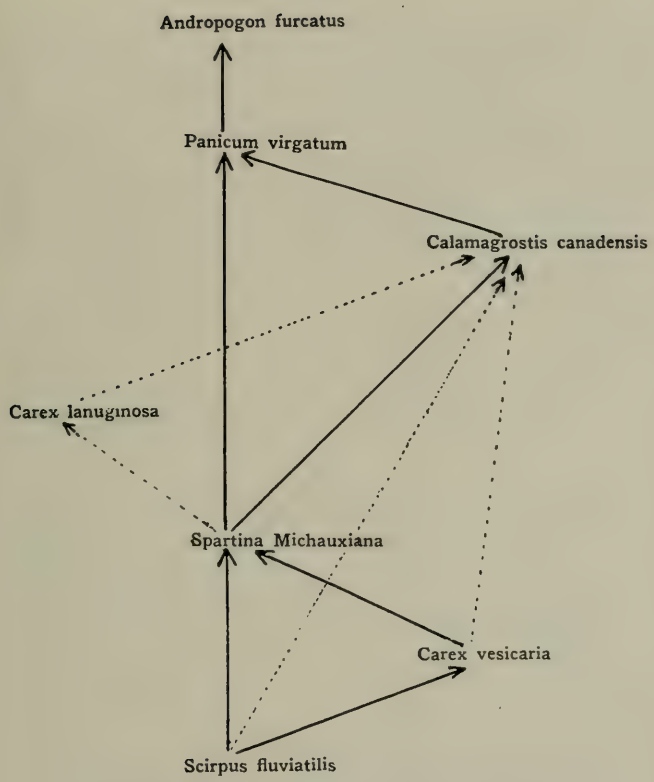


FIG. 1. Diagram showing the successions of the plant associations from swamp to prairie on the flood-plain of the Mississippi River at Savanna, Illinois. The dotted lines represent local exceptions of rare occurrence. See Plates XLVIII–LIII.

The data obtained from the surveyors' reports show that the greater amount of undisturbed flood-plain prairie occurs along the Mississippi River. Similar areas, however, occur along the Illinois and smaller rivers. The driest of these flood-plain prairies found, are along the Desplaines River near Riverside, in Cook county. These areas have been

modified by pasturing and are dominated by *Andropogon furcatus* or its ecological equivalents.

The data in Figure 2 were obtained from a 220-acre field along the Illinois River five miles west of Morris, in Grundy county. The trend of associations on the unpastured portion are practically identical with those along the Mississippi.

It is important to note that the data in Figure 2 also show the effect of grazing upon the natural prairie flora. Practically every one of the dominant species occurring under natural conditions is replaced by some other species. *Scirpus fluviatilis* is replaced by *Typha latifolia; Spartina Michauxiana* and *Calamagrostis canadensis,* partly by Carex and Juncus but mostly by *Agrostis alba; Panicum virgatum,* partly by

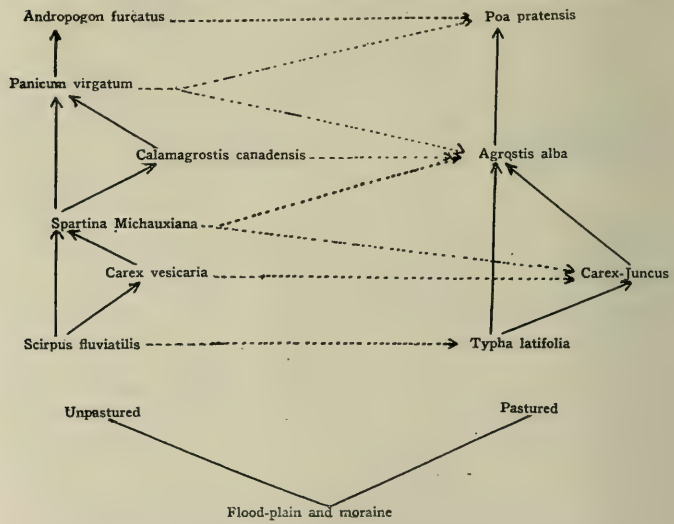


FIG. 2. Diagram showing the successions of the plant associations on pastured and unpastured areas on the flood-plain of the Illinois River in Grundy county. The dotted lines indicate the successions brought about by grazing.

Agrostis alba and partly by *Poa pratensis;* and *Andropogon furcatus,* entirely by *Poa pratensis.* Not only are these primary species destroyed by grazing, but practically all of the secondary species are likewise eliminated. It may readily be seen that areas not subjected to intense grazing or areas that had been pastured in the past and then allowed

to revert to natural conditions would exhibit a mixture of associations of native and cultivated grasses impossible to decipher on an ecological basis unless ecological equivalents are recognized and appreciated. The above data are important in suggesting an explanation of the conditions existing on the Chicago plain, to be discussed later.

According to the county soil reports (3) the surface soils of these flood-plain areas consist in the main of brown silt loam and sandy silt loam derived from materials washed from the upland and deposited at periods of overflow. Usually there is present a considerable amount of sand. The subsoil as a rule is sandy silt loam, sand, or clay. In some of the swamps peat is abundant. Enormous areas of peat occur on the wide flood-plains of the Rock and Green rivers in Bureau, Henry, Lee, Whiteside, and Rock Island counties. The peat beds occur in depressions between the sand hills and in morainal depressions.

With the exception of peat all of these soils are rich in the minerals required by plants, and their plant associations are similar. Peat, on the other hand, is exceptionally rich in organic material and poor in potassium, but its plant associations are dominated by the same species that dominate wet areas on other types of soil. *Calamagrostis canadensis* is particularly prominent on wet peat. The height of the water-table and not the chemistry of the soil is the limiting factor determining the order of associations.

Some progress toward an explanation of the order of occurrence of the associations in the hydrarch succession has been made, but the data at present are little more than suggestive. Miss Hayden (13, 14) found that parenchyma and aerenchyma are more prominent in roots and rhizomes of swamp plants than of upland plants on the prairie of central Iowa, and that the leaves of upland plants have thinner epidermal walls, a greater amount of palisade-tissue and more compact mesophyll, and are more frequently hairy than leaves of plants on the lowlands. We are greatly in need of more ecological anatomy of this type which should be extended to include the dominant species of the prairie associations. It should also be checked by experiments similar to those of Cannon and Free (2) to determine the effectiveness of aerenchyma in supplying oxygen to roots in soils of low oxygen content. It should further be checked by actual measurements of transpiration rates to determine the comparative effectiveness of the various modifications of leaf structure. Transeau in some unpublished work has found that a heavy cuticle on leaves does not necessarily mean that they have a lower transpiration rate than leaves with thin cuticle. Sayre (21) found that hairs on mullein leaves do not retard transpiration under ordinary intensities of wind and light, and that eighty per cent. of the transpiration from these leaves is stomatal transpiration. Some of the modifications in leaf structure, therefore, affect only the twenty per cent. of transpiration directly from the epidermal cells, and there is great danger of overemphasizing their importance in the absence of experimental data.

The Hydrarch Succession (b) on the Old Lake Bed of Lake Chicago

The geological history of this region has been described in detail by Leverett (17) and Salisbury and Alden (20). The following summary is given to bring out more clearly the relation of the vegetation to the present physiography. During the retreat of the Wisconsin ice sheet, a temporary balance between the melting back of the glacial front and its forward movement resulted in the formation of the Valparaiso moraine. With further recession of the glacier this moraine served as a dam which hemmed in the water from the melting ice, forming a lake known as Lake Chicago. The surface of this lake was at one time 60 feet above the present level of Lake Michigan. An outlet through the Desplaines River gradually lowered the level of the lake until the glacier receded far enough to open an outlet to the north which resulted in the withdrawal of the water from the Chicago plain. Three old beach lines, sixty, forty, and twenty feet above the present level of Lake Michigan, show that the outlet to the north was interfered with a second and third time, and that a lake again occupied the area in question. With the final retreat of the glacier and subsequent drainage through the St. Lawrence System the water was gradually drained from the region between the Valparaiso moraine and the present beach of Lake Michigan. The area thus exposed was a flat, level plain, poorly drained, and abounding in lakes and swamps which have been gradually filling with vegetation.

The old beaches and sand-dunes areas are forested, but the remainder is largely prairie or swamp land. Much of the present undisturbed prairie is considered too wet for agricultural purposes except in dry seasons. In some of the drier portions, however, cultivated plants ecologically equivalent to *Panicum virgatum* and red top could be grown. Roadways and ditches have recently been established along the main section lines, and in some cases city blocks have been laid out. This artificial drainage has reacted to some extent upon the natural vegetation, and it is undoubtedly a partial cause of some of the disturbances noted in the natural plant associations of this area.

The drainage ditches are marked by a line of cottonwoods and a few willows, mostly *Salix amygdaloides,* though in some places swamp grasses are found refilling the ditches. These trees are growing in the bottom of the ditches where the prairie turf has been completely destroyed.

This prairie is exceptionally rich in organic matter, peat sometimes occurring. The subsoil is mostly glacial till, forming poor subsoil drainage, but local areas of sand and rock also occur. Owing to the flat surface and the impervious clay subsoil, much of the surface soil is usually saturated during the wet spring months. Later in the season the water content under present conditions of drainage may drop below the wilting coefficient. Harvey (12) has shown that during the summer of 1911 the

water content of this soil at a depth of 7.5 cm. was below the wilting coefficient during most of the period from the first of July to the last of September, and at a depth of 25 cm. the water content was but a little above the wilting coefficient for the same period. Plants growing throughout the season, therefore, must be able to maintain a suitable water balance through the two opposite extremes of soil-water content. Since the roots of many prairie plants grow deeper than 25 cm., we need more data on the wilting coefficient in relation to depth of root systems of the dominant plants in the different associations.

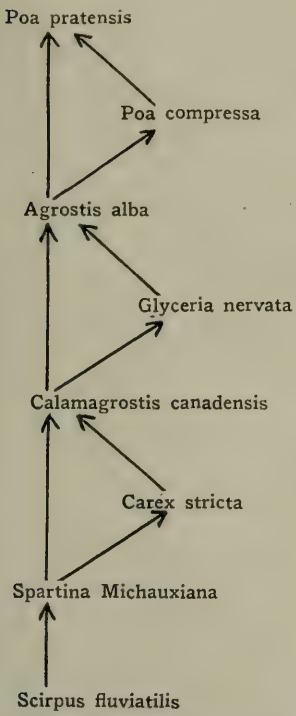


FIG. 3. Diagram showing the succession of the plant associations around a pond near Chicago Lawn on the old lake bed of Lake Chicago. Disturbance by man has made possible the occurrence, here, of associations dominated by Glyceria and cultivated grasses. See Plate LIV.

More than 4,000 acres of this prairie are included in this survey. Figure 3, shows the trend of associations from a small pond near Chicago Lawn. The prominence of the cultivated grasses, Poa and Agrostis, in this locality is very probably the result of the suburban habit of "staking cows out to pasture", but, as will be shown later, other factors may also be important here.

In Figure 4 an attempt is made to summarize the relations of the principal associations on the Chicago prairie including those of cultivated grasses. No attempt is made to include all the associations in the deeper swamps. These have been described in detail by Sherff (23) and Gates (6).

The data show that there is a far greater complexity of associations on this prairie than on those discussed above. In the first place the appearance of associations dominated by *Agrostis alba* and by the blue grasses, *Poa pratensis* and *Poa compressa*, represents a condition in this prairie not characteristic of the natural prairies of the state. There is no evidence in the older descriptions of the prairie that either of these species was present in the original prairies of the

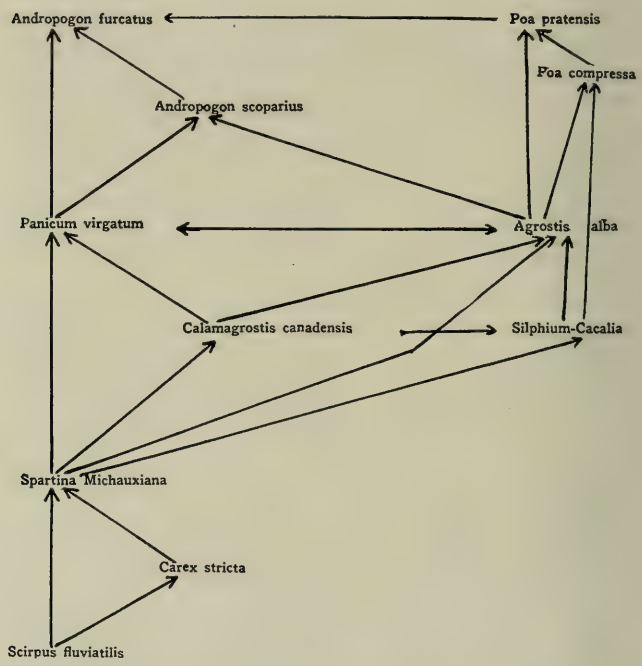


FIG. 4. Diagram showing the successions of the principal associations on the old lake-bed of Lake Chicago, including those of cultivated grasses. See Plates LI, LIV–LXIV.

state. Their presence today is the result of their introduction and use in cultivation. The blue grasses were apparently introduced from Europe. Waller (30) finds that the early settlers of Virginia and Kentucky looked upon *Poa pratensis* as a dangerous introduced weed and some of them prophesied that it would some day drive the farmers out of the country. A wealthy plantation owner, fearful lest the blue grass would ruin his pastures, ordered his slaves to dig it out and burn it. The early settlers of Illinois say that blue grass came into the state following the destruction of the native grasses by cultivation and grazing. The prominence of these cultivated grasses on the Chicago prairie is indicative of disturbance by man and raises the question as to how far this prairie may

be considered representative of original conditions. The data in Figures 2 and 5 show that grazing results in the coming in of cultivated grasses. A knowledge of the amount of grazing this prairie suffered during the early development of Chicago is wanting. During the last forty years the grass has been cut annually in July. This is rather more detrimental to the late fall grasses than to the earlier grasses in that it destroys their vegetative growth shortly before time for fruiting and usually prevents them from seeding. In addition, fires started by trains contribute to the disturbance of the composition of associations which obtained under natural conditions of competition. Artificial drainage has lowered the water-table and extended the seasonal period during which the water content of the soil is below the wilting coefficient. During the slow readjustment of the associations of native species to the disturbing conditions other species have a chance to obtain a temporary foothold. These cultivated grasses are not able to invade the undisturbed native associations, and the period of their dominance in disturbed areas is dependent upon the continuation of the disturbances.

In the second place a number of coarse herbs become more conspicuous, notably *Silphium laciniatum, Cacalia tuberosa,* and *Liatris spicata,* which usually follow Spartina and Calamagrostis and may be found in pure or mixed stands of various combinations now occupying the greater part of local areas. *Apocynum cannabinum* var. *hypericifolium* is also occasionally abundant at this stage. On the slightly drier prairies *Silphium terebinthinaceum* and *Eryngium yuccifolium* are sometimes abundant.

Finally, the occurrence of a mixed association dominated largely by *Andropogon scoparius* and *Sporobolus heterolepis* following *Agrostis alba* and *Panicum virgatum* on the low prairies seems out of harmony with the xerophytic nature of these grasses. The same species also dominate a portion of the Calumet beach near Chicago Ridge where it has been deforested. In this latter situation these species are in a xerophytic habitat characteristic of them, but on the low prairie they appear in the hydrarch succession which is not characteristic of them. Isolated clumps and small patches of *Andropogon furcatus* occur with them. In my opinion the above factors explain the occurrence of cultivated grasses in these prairies and also account for the Andropogon-Sporobolus association in the hydrarch succession and for the notable abundance of coarse herbs. During the period of readjustment following disturbance, the speed of migration becomes an important factor which in turn depends upon the proximity of plants producing an abundance of readily dispersed seeds. *Andropogon furcatus* is not nearly as abundant on the hills and sand dunes near Chicago as are the other grasses, and the latter, therefore, have a chance to obtain the first foothold on drained and denuded areas. It appears that the composition of the associations on the Chicago prairie is scarcely more representative of the composition of the earlier natural associations than are those found on railway rights-of-way.

On the other hand, if we disregard the blue grass and red top in any given area or choose areas in which they have not gained a foothold the order of succession of the associations of native grasses is readily seen. With the exception of the presence of *Andropogon scoparius* and *Sporobolus heterolepis* in some places this succession of associations does not differ materially from that of the flood-plain prairies already described.

Andropogon furcatus does not play a very important rôle on the Chicago prairie. Under natural conditions most of this prairie was too wet for Andropogon. As noted above, it is frequently found on the higher ground, and it is most abundant in the neighborhood of the artificial drainage ditches. One of the areas that shows clearly the succession from *Panicum virgatum* to *Andropogon furcatus* on this prairie is about one half mile southwest of Oak Ridge (Plate LIX). The fact that this particular prairie is separated from the Wabash railway by a small stream is probably significant. The conditions on this area are more like those in other parts of the state. Coarse herbs are present but they occur as scattered individuals of secondary importance. Red top and blue grasses are not abundant. Special attention should be called to the fact that owing to their much greater height the native grasses readily crowd out the cultivated grasses in regions undisturbed by man. Mowing checks but does not entirely prevent the encroachment of *Andropogon furcatus* in associations of *Poa pratensis*. This fact was obtained from observations on carefully mapped areas about one mile northwest of Ashburn just north of 87th Street on some of the best drained portions of this prairie. While the observations on this particular area were limited to a period of only three years, a slight increase in the amount of Andropogon was evident. The data recorded in Figure 6 show still more conclusively that when man does not interfere too much, *Andropogon furcatus* will crowd out our cultivated grasses.

Portions of the Chicago prairie have been cultivated from one to a few years and then abandoned. In all cases so far observed these abandoned areas have reverted again to prairie. *Agrostis alba* is usually the first grass to get a foothold. Coarse herbs likewise get an early start. Then blue grass and Andropogon follow. The reversion to prairie is not entirely due to the absence of "seed trees". Seedlings of cottonwood frequently make a start, but owing to subsequent mowing and burning they are usually destroyed.

The Hydrarch Succession (c) in Morainal Depressions

The morainal depressions vary in size from the small ones found in terminal moraines to the much more extensive ones of the ground moraine. Many of these depressions were formerly post-glacial lakes which became partially drained by subsequent gradation. As would be expected, the greater area of these depressions today occurs in the less

eroded Wisconsin glaciated region. The horizontal or geographical succession of associations in these depressions at present is important in showing the vertical or historical succession of associations during the gradual filling and draining of the sloughs since glacial times. Much of the *Andropogon furcatus* prairie of the state originated in this way.

Mr. L. Wiles, of Dundas, Illinois, who plowed some of the virgin prairie in Vermilion county before artificial drainage was established, says that the only tillable soil between the rivers and sloughs was that covered by tall bluestem (*Andropogon furcatus*), and that usually the farmers were not able to plow quite all of the Andropogon prairie but had to leave a narrow strip of it surrounding other grasses bordering the sloughs in the depressions. In many places in the farming district these depressions have not yet been completely drained, and where grazing has not been too severe the successions of the native grasses are still evident. In some places, as in the depressions near Camp Grove and Lacon in Marshall county, all the associations up to and including *Andropogon furcatus* may be found, while in other depressions farming has destroyed the Andropogon, and sometimes Panicum, entirely. A summary of these associations made from observations of more than twenty morainal depressions is given in Figure 5.

Vestal (28) has described the associations about a small depression on the Valparaiso moraine on the boundary line of Cook and Dupage counties. While this prairie has some indications of the influence of civilization, such as the presence of red top and blue grass previously mentioned for the Chicago prairies, it is of interest as a description of a more xerophytic type of prairie characteristic of clay soils in the vicinity of forests. The hydrarch series is somewhat similar to that already described for the Chicago prairie, including the abundance of cultivated grasses and herbs. On the most xerophytic areas of the upland *Andropogon scoparius* is dominant. *Silphium laciniatum* occurs in patches as a local dominant. Several other coarse herbs are of frequent occurrence.

The effect of grazing shown in Figure 5 is the same as that already discussed in connection with the flood-plain prairies. The conversion of natural prairie grass-lands to blue grass and red top by pasturing has occurred throughout the entire state. This fact is of interest both to the plant ecologist and to the farmers. In the first place the natural prairie grasses of any habitat serve as an indicator of the kind of cultivated grasses most suitable for that habitat. This might be further extended to include all the agricultural crops of the region (Waller, 29, 31). In the second place it points clearly to the best method of obtaining permanent pastures. The data show that Kentucky blue grass is the dominant pasture grass of all the upland prairie region, and when once established it remains a permanent feature. On the other hand timothy and red top pastures are in general short-lived but have the advantage of establishing themselves more quickly. It is a well known fact that the blue-grass pasture sod can not be obtained the first season after seeding. This difficulty, however, is readily overcome by seeding

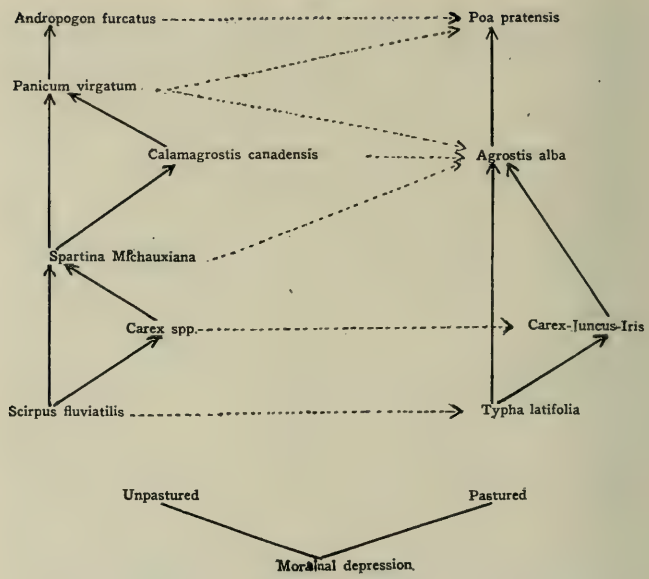


FIG. 5. Diagram showing the plant associations and hydrarch successions in morainal depressions. The dotted lines indicate the changes brought about by grazing.

to a mixture of blue grass with timothy and red top and allowing a few years for the blue grass to establish itself and crowd out the other grasses, except in low places where red top is a dominant pasture grass. On fertile loamy soil this succession will occur within three or four years, but on clay soils a somewhat longer time is required.

With the foregoing associations and their successional relationships in mind it is of interest to compare them with the associations found on the more extensive shallow depressions of the ground moraine. This can be done at present only by having recourse to the relic patches of prairie plants along railway rights-of-way and fence-rows (Plates LXV–LXX). When this comparison is made, the same general associations frequently interspersed with patches of coarse herbs and cultivated grasses are met with again in the same order from lowlands to upland. This comparison also shows that most of the prairie areas of the older glaciated regions of the state had reached the *Andropogon furcatus* stage before they were disturbed by man, while large areas in the Wisconsin

glaciation were still dominated by *Spartina Michauxiana, Calamagrostis canadensis,* and *Panicum virgatum.* Owing to the clean farming methods practiced in this part of the state it is now very difficult to estimate the percentage of swamp prairie formerly occurring on the present well-drained farms. But the postglacial history of this area is still clearly written in the soil. The wide extent of the deep black soils points to a long postglacial period in which swamps dominated by sedges and swamp grasses covered large portions of this glaciation. With the gradual filling and drainage of these extensive swamps the more mesophytic prairies arose. Soil maps showing the comparative depth of the dark humus soil could be used in determining the extent of associations and also in the estimation of land values.

Mr. Wiles estimated that from 70 to 90 per cent. of the area of the isolated prairie tracts separated by streams near his home in Vermilion county was dominated by an almost pure stand of *Andropogon furcatus,* the remainder by slough grasses, sedges, and rushes. He stated, however, that more abundant and extensive sloughs were present in the prairie tracts northwest of Vermilion county. Farmers who helped drain Douglas county say that the area formerly covered by sloughs and shallow lakes greatly exceeded the area of tillable land in that county.

2. THE XERARCH SUCCESSIONS

The Succession (a) on Upland Glacial Soils

The succession of associations leading from swamp to the upland prairie was found in every case to terminate in an *Andropogon furcatus* association. This raises the questions of the amount of the upland prairie soils dominated by this grass and the nature of the successions from the more xerophytic areas on upland glacial soils and sand.

In this survey emphasis was placed upon the Wisconsin and the Lower Illinoisan glaciations. On the former the most typical upland prairie soil is a brown silt loam, on the latter it is a gray silt loam poorer in organic matter and generally less fertile. Both of these surface soil types are underlaid at varying depths with the typical clays of the glacial till. Outcrops of these glacial clays are among the most xerophytic areas of the prairie.

Owing to the value of this type of land for agriculture, it is now practically all under cultivation. The few small relics of *Andropogon furcatus* prairie in the vicinity of morainal depressions previously discussed and similar patches near forest borders constitute the only prairie tracts of this type found in the Wisconsin glaciation. On the southern Illinoisan glaciation several small tracts varying in size from a fraction of an acre to 2 acres were found. With the exception of the exposed clay areas these are all *Andropogon furcatus* prairies.

Additional data were obtained from railway rights-of-way, old line-fences, and from individuals who had lived on these prairies be-

fore they were plowed. Both of these sources of information have their limitations. The railway rights-of-way have been subjected to grading, artificial drainage, annual cutting, and burning, and many have been cultivated at times. As a result the original associations have been frequently greatly modified or entirely destroyed. Natural competition is interfered with, and the observed composition of the associations and habitat-range of individual species may not correspond to original conditions. It is also of interest in this connection to call attention to the fact that patches of natural prairie plants on these rights-of-way may not always be relics of the original prairie but the result of secondary successions culminating in the original prairie plants.

This fact is clearly illustrated in many places along the Indianapolis branch of the Illinois Central Railway. This right-of-way was originally 50 feet wide. In 1897 it was made 80 feet wide by enclosing 15 feet of farm land on each side. The diagram, Figure 6, represents the succession of associations that has occurred on a strip of this abandoned farm land near my father's farm one mile west of Wheeler in Jasper county.

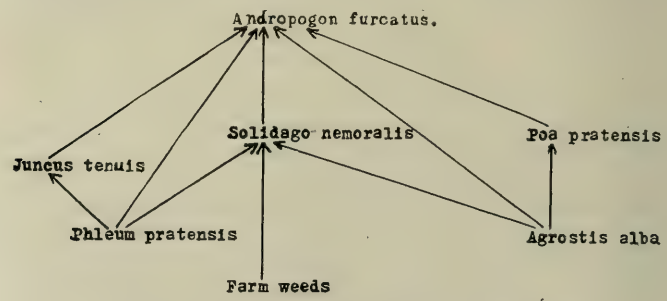


FIG. 6. Diagram showing secondary successions on a railway right-of-way formerly under cultivation near Wheeler, Illinois.

At the time of widening the right-of-way the land on one side of the tract was a timothy pasture, on the other side it was under cultivation. In some places *Andropogon furcatus* occurs now in almost pure stand and might well be considered original prairie if its history were unknown. This reversion to the natural prairie plants may be seen anywhere along this right-of-way where a sufficient number of relic prairie plants existed on the old right-of-way. Another instance of this, on the Baltimore and Ohio Railway in Clay county, is illustrated in Plate LXX. The area now covered with *Andropogon furcatus* was formerly forested. The greater part of the 90 miles of this right-of-way

from Odin to Olney is covered by *Andropogon furcatus,* and much of it is original prairie sod.

Still another type of reversion to the *Andropogon furcatus* prairie may be seen on eroding banks and slopes along these rights-of-way. Many instances were noted where *Andropogon scoparius* dominated the slopes of valleys while the upland and base of the slopes were dominated by *Andropogon furcatus.* The successions of these associations accompanying base-leveling in such cases is obvious. *Sorghastrum nutans* and *Sporobolus heterolepis* were also found on these slopes but generally as secondary species. Where erosion is rapid coarse herbs are abundant, but where erosion is slowed down by decreased gradients and consequent greater stability of soil they become scattered secondary members of the grass associations. In cases where the natural grasses have been entirely eradicated these coarse herbs prevail perhaps indefinitely.

In addition to railway rights-of-way in the Illinoisan glaciation old fence-rows harboring relic patches of prairie plants are abundant. When land adjoining these fence-rows is sowed to meadow grasses the cultivated grasses are gradually invaded and crowded out by *Andropogon furcatus.* One instance was observed where this native grass occupied an area of timothy meadow to a distance of 40 feet, and areas 10–15 feet in width are common.

With regard to limitations in basing conclusions upon statements made by the early settlers the principle that safety lies in numbers was adhered to, and in practically all cases specimens of the plants in question were at hand. No less than 30 individuals were questioned with regard to the original prairies of the Southern Illinoisan glaciation. Many of these had spent from 20 to 30 years on the virgin prairies and on account of economic, medicinal, or esthetic reasons were familiar with many species of prairie plants.

The data obtained from the early settlers and a careful study of the prairie relics seem sufficient to reconstruct rather accurately the original prairies of the Southern Illinoisan glaciation. The low prairie was dominated mainly by *Spartina Michauxiana, Calamagrostis canadensis,* and *Panicum virgatum,* while the more extensive prairie was dominated by *Andropogon furcatus.* Coarse herbs grew only as scattered individuals among the grasses. On the exposed clay *Andropogon scoparius* was abundant, and associated with it were many coarse herbs. A mixed association consisting of the two Andropogons, *Sorghastrum nutans,* and *Sporobolus heterolepis* may have occurred in transition zones on some of these clay areas.

Turning now to the Wisconsin glaciation the same sources of information exist, but they were less fruitful. From the data available it is certain than *Andropogon furcatus* was the dominant grass of the upland prairies. The points in question concern the probable rôle played by coarse herbs and by more xerophytic grasses, particularly *Andropogon*

scoparius, and the probable extent of mixed associations. In the *Andropogon furcatus* prairies remaining in morainal depressions and the small areas in the vicinity of Chicago coarse herbs occur only as scattered individuals, as in the Southern Illinoisan glaciation. The older writers speak of these prairies as a "sea of grasses", and it is probable that coarse herbs did not occupy very large areas, as their presence would certainly have called forth exclamations from the men of those days. Wherever the prairie grasses have been greatly disturbed along railway rights-of-way, both north and south, these coarse herbs become conspicuous, and this has probably led many to ascribe to them more prominence than they deserve. Gerhard and others report them as being abundant on hillsides and near forest borders, and they may have been rather prominent on the shallow soils of morainal ridges.

The xerophytic grass association dominated by *Andropogon scoparius* is the characteristic association of these shallow soils. Relic patches of this grass are most frequently found on the broken topography near woodlands where the subsoil has been exposed by erosion. As in the southern part of the state, *Sorghastrum nutans, Sporobolus heterolepis,* and coarse herbs are also more conspicuous in these areas. Vestal (28) finds that this association is not very extensively developed in the upper Wisconsin glaciation. The data obtained in this survey agree with his statement.

The available data bearing upon the extent of mixed associations in this region are rather insufficient for quantitative estimates. In the Southern Illinoisan glaciation mixed associations were of minor importance as most of that region had reached the climax stage of development and was dominated by but one species, *Andropogon furcatus.* It is probable that mixed associations representing a transition stage in succession to this climax from the drier uplands may have been more extensive on the younger topography of the Wisconsin glaciation, but conclusive evidence is wanting.

From my records it appears evident that under the most favorable natural conditions the dominant species shown in the previous diagrams of this report must have occurred in almost pure stands; that coarse herbs were not abundant except on eroding soils and near forest borders; and that mixed associations were limited largely to transition zones. This conclusion was corroborated by every early settler with whom I talked and also by Dr. John H. Schaffner (22), who lived on the Andropogon prairies in Kansas and had many opportunities to see them in their natural conditions. They all report that in the best growing seasons *Andropogon furcatus* grew so tall that a man sitting on a horse could not see over it, and that the location of cattle and horses could frequently not be determined except by the waving of the tall grass as they passed through it. This height together with its production of a close sod and dense vegetative growth was sufficient to exclude most of the other prairie plants. Dr. Schaffner also reports that *Andropogon scoparius* generally occurred in very pure stands, and that coarse herbs

were not abundant in either of the Andropogon associations but might occur abundantly on eroding soils. Some of the plates accompanying this report show these same features for *Spartina Michauxiana, Calamagrostis canadensis,* and *Panicum virgatum.*

To sum up, both the historical data and the data obtained from relic prairie areas lead to the conclusion that *Andropogon furcatus* is the climax grass of the whole upland prairie region of the state, and that in the successions leading to this climax from the more xerophytic uplands and exposed clay soils *Andropogon scoparius* is the most important species. Figure, 7 shows the successions of associations that may occur in this xerarch series.

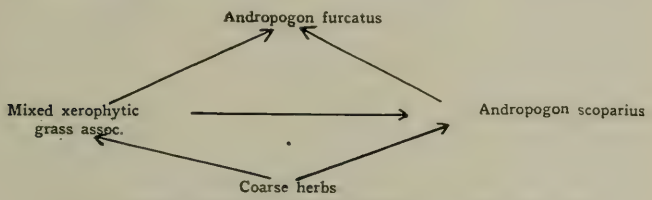


FIG. 7. Diagram showing the principal associations in the xerarch succession on xerophytic upland soils.

During the long postglacial period forests working back from the water courses invaded these upland prairie soils. The progress of this invasion as would be expected is much farther advanced in the Lower Illinoisan glaciation than in the Wisconsin glaciation. While this encroachment of the forest on the prairie is generally considered to have kept pace with the development of drainage and the soil erosion involved, there are rather extensive areas in which the encroaching forest preceded erosion. Since these forest soils bordering the upland prairie soils had the same origin, the differences in them today are largely a result of their floral history. In this connection the county soil reports (3) have some very interesting data showing the effect of vegetation upon soil types. The organic matter of the forest soils ranges from about 25–50 per cent. of the amount present in the adjoining prairie soils. This gives the prairie soils a much darker color than the forest soils and is the result of a more complete decomposition of the plant remains of a forest than of a prairie. To quote from one of these reports: "The leaves and twigs of the trees fall upon the surface of the ground and decay completely; whereas the prairie grasses form a mass of roots in the soil which, when they die, are prevented from complete decay by the absence of sufficient oxygen. In this way prairie grasses and other plants cause a gradual accumulation of organic matter. If prairie land becomes forested the organic matter is slowly diminished to a low point." This statement apparently is not intended to apply to flood-plain forests, where deposition during

overflows is an important factor in soil fertility, nor to the occasional small forest areas that have developed from swamps in which the slowly decaying organic matter accumulates under water during the greater part of the year. The conditions described above are more prominent in the older glaciated regions, where we find the most extensive areas of forest encroachment on pre-erosion topography.

The data in these soil reports also show a lower content of calcium in forest soils than in the adjoining prairie soils. This difference is much more pronounced in the subsurface soils and subsoils than in the surface soils, rendering them more acid than the adjoining prairie soils. Forest vegetation when compared with prairie vegetation therefore retards the accumulation of organic matter and accelerates the drain on calcium. Certain authors have suggested that the greater content of calcium in prairie soils may be one of the causes of the prairie. The above facts indicate that prairie vegetation greatly retards the rate at which calcium leaches from the soil.

The farmers of the state have been slow in recognizing this effect of the floral history upon the present value of soils. In my own community in the Southern Illinoisan glaciation the clearing and cultivation of forested areas always seemed to have an alluring appeal entirely unrelated to economic values. Many of the farmers continued to clear the forest in spite of the fact that some of the forested areas after ten to fifteen years of cultivation yield no better crops than adjacent prairie areas that have been cultivated for forty years. Many of the slopes formerly protected by forest vegetation have been cleared, farmed for a few years, and then abandoned to the forces of erosion. An intelligent constructive forest policy that can be taught and convincingly explained to the farmers is the only hope for remedying these regrettable conditions.

The Xerarch Succession (b) on Sand

The sand prairies of the state have been described in detail by Gleason (9, 10) and Vestal (27); consequently they have received only minor attention in this survey. The following description deals mainly with the more general features which tend to show the relation of the floral successions on sand to those of the soil types previously discussed. Both of the above sources of information have been drawn upon in this report. Evidence collected by Gleason shows that most of the sand prairies were covered with a carpet of vegetation when settlements were begun in this region. Subsequent plowing and pasturing, however, has led to the exposure of large areas of sand to wind action and the development of "blowouts". Owing to frequent movement of the sand by wind, the revegetation and stabilization of these xerophytic sand areas is a slow process, and progressive successions are often less prominent than retrogressive ones. The most xerophytic prairies of the state occur in these sand areas, and as Gleason has already pointed out we have here the greatest representation of typically western plants. In fact the

vegetation of the more xerophytic sand areas is more representative of the sand-hill vegetation of Kansas and Nebraska than of the Great Plains or the Prairie.

With the establishment of a pioneer association sufficient to prevent the erosive action of the wind, conditions become less severe and further growth of a less xerophytic type is favored. As the vegetation encroaches and establishes itself upon the sand, the accumulation of organic matter from decaying roots and tops of successive associations results in physical changes in the soil which slowly approach conditions existing on the more mesophytic prairies. The more important of these changes is a decrease in the extremes of temperature and an increase in humus with a consequent increase in soil stability and soil water. Gleason (10) has shown that the evaporation rate of the air also gradually decreases from one association to another. Each association thus improves conditions and paves the way for its successor, ultimately leading to the climax association of the region.

Observations were made on the sand areas at Hanover, between Savanna and Albany, at Oregon, and in the northwestern part of Bureau county. The succession of the principal associations leading to prairie in these areas is given in Figure 8.

The *Panicum pseudopubescens* association is most frequently found in the vicinity of blowouts, where it is a stage in the retrogressive succession from the bunch-grass association to the blowout association. Plate LXXI represents such a stage with the blowout just beginning, and shows the relative amount of the sand that may be occupied by this species. The secondary species are relics of the bunch-grass associations previously destroyed by the wind.

With the further development of the blowout *Panicum pseudopubescens* is replaced by the blowout association, which Gleason further subdivides into four distinct "associations." First, the basin of the blowout, where the sand is being removed by the wind. The vegetation of this "association" is very meager and is composed of a few scattered perennials persisting from the *Panicum pseudopubescens* association. Chief among these are *Acerates viridiflora* and its varieties *lanceolata* and *linearis, Lithospermum Gmelini, Euphorbia corollata*, and *Lespedeza capitata*. Second, the windward slope, where the sand is being removed by both wind and gravity. The vegetation of this "association" consists of relics of the *Panicum pseudopubescens* and bunch-grass associations which have been undermined at the top and have gained a foothold while sliding down the slope. This association is limited to perennials, among the most important of which are *Panicum pseudopubescens* and *Selaginella rupestris*. Third, the lee slope, or "blowsand association," over which the sand is being sprayed by the wind. The vegetation of this association consists mainly of annuals characteristic of the bunch-grass association. Gleason lists 31 species for this association, of which *Aristida tuberculosa* is the pioneer. This species is common to all the areas studied. Other important species such as *Diodia teres, Paspalum setaceum, Commelina*

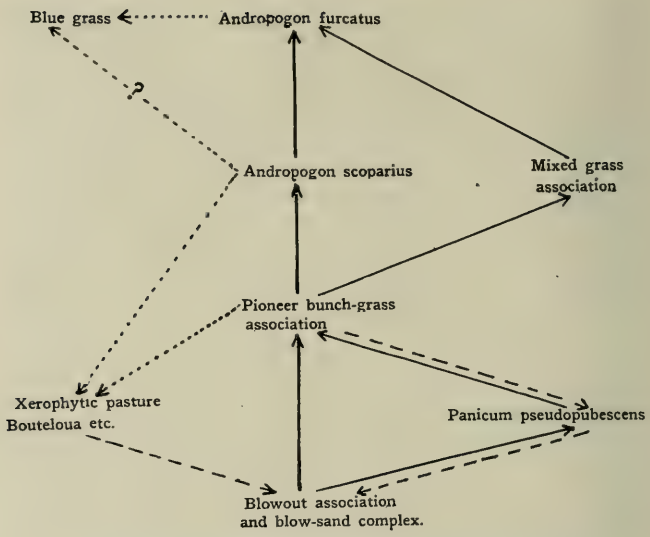


FIG. 8. Diagram showing the interrelation of the principal associations leading to prairie on sand. The broken lines represent retrogressive successions resulting from blowouts. The dotted lines represent successions resulting from grazing. See Plates LXXI–LXXV.

virginica, and *Cenchrus carolinianus* are more local in their distribution. Lastly, the "deposit association," composed chiefly of such dune-forming species as *Rhus canadensis*, var. *illinoensis*, *Ceanothus americanus*, *Tephrosia virginiana*, *Panicum virgatum*, and occasionally *Calamovilfa longifolia*. To this list Vestal (27) proposes to add a fifth association, the "blowsand complex", which arises from the continued growth of a large blowout or by the confluence of a number of blowouts. The vegetation is variable and is composed mainly of annuals as in the case of the blow-sand association.

The meager vegetation of these five "associations" is of little consequence in the stabilization of the sand. The first permanent step in the development of vegetation on denuded areas is accomplished by the pioneer bunch-grasses which succeed in getting a foothold in any of these associations. *Selaginella rupestris* is also an important pioneer invader in these areas at Hanover and Savanna. The order of the entrance of the grasses is not definitely known, though, as Gleason has pointed out, it depends largely upon the nature of the neighboring areas of the

bunch-grass association. Invasion may be affected by a single species or by two or more species in common. The most important of these pioneers observed by the writer are *Panicum pseudopubescens, Paspalum setaceum, Sporobolus cryptandrus, Leptoloma cognatum, Carex Muhlenbergii,* and *Cyperus Schweinitzii.* On the deposit associations *Panicum virgatum* may serve as the starting point of the bunch-grass association.

The pioneer bunch-grass association may be dominated by a single species or by a mixture of several species. The most important of the grasses in addition to those listed above are *Bouteloua hirsuta, B. curtipendula, Eragrostis pectinacea, Koeleria cristata, Stipa spartea,* and *Andropogon scoparius,* all of which may occur as local dominants. With decrease in xerophytism the pioneer bunch-grasses are replaced by *Andropogon scoparius* or a mixed grass association in which both species of Andropogon and sometimes *Sporobolus heterolepis* are the prominent members. *Sorghastrum nutans* and *Panicum Scribnerianum* also increase in abundance in these associations. At first the secondary species are largely relics of the former bunch-grass association, but in the later stages these are largely crowded out by Andropogon and partly replaced by secondary species common to the Andropogon prairies elsewhere in the state. In the most mesophytic stage of the *Andropogon scoparius* association the open tuft-like growth characteristic of the pioneer bunch-grass association is replaced by a close sod (Plate LXXIV). These associations are not abundant today and were found only on low dunes, in depressions between dunes, and on railway rights-of-way where they had been least disturbed by agricultural practices.

The most mesophytic areas of the sand are dominated by *Andropogon furcatus.* Vestal (27) reports *Andropogon furcatus* dominating parts of the "black-soil transition association" on sand which he finds has reached its most advanced stage in the Havana region "in places near Devil's Neck, in places east of the several forested dune areas, and particularly at the eastern border of the sand plain". Most of the sand prairies of this type have been either plowed or pastured. Plate LXXV shows an almost pure stand of *Andropogon furcatus* on a low dune some two miles south of Savanna. This dune is probably not more than 20 feet above the river. One side grades off into the flood-plain, and the remaining three sides are bordered by small lakes. It has escaped both plowing and pasturing. About half of the dune is dominated by *Andropogon furcatus,* the remainder by *Andropogon scoparius.* A similar area was found toward the base of a sand dune adjoining a swamp preserved for hay in the northern part of Bureau county. The older residents of this region report an abundance of tall bluestem on the low sand hills between the swamps, and an abundance of both tall and low bluestem, frequently mixed with other grasses, on the higher dunes.

A large part of the sand area in Bureau county has been subjected to pasturing, and a blue-grass pasture has resulted in many cases. When the pioneer bunch-grass association or an early stage of the *Andropogon*

scoparius association on sand is pastured, a xerophytic pasture results in which the prominent species are *Bouteloua hirsuta, Leptoloma cognatum, Panicum pseudopubescens, Paspalum, setaceum, Eragrostis pectinacea,* and *Cyperus Schweinitzii.* The presence of the blue-grass pastures therefore indicates a rather advanced stage in the development of the sand prairie, probably either a late stage of the *Andropogon scoparius* or mixed grass association, or an *Andropogon furcatus* association.

Apparently this last association was rarely developed on the higher sand areas. Gleason estimates that on the sand prairies as a whole at least two thirds of the surface was originally occupied by a mixed bunch-grass association varying all the way from areas dominated by the pioneer grasses to those in which the Andropogons were abundant.

It would be of interest to both plant ecologists and farmers if a tract of the present cultivated sand prairies of the Savanna region could be set aside and allowed to revert undisturbed to natural conditions. The ecologist could determine more definitely the order of succession of the natural grasses on sand. At the same time the agriculturist would have a means of determining how long it would be necessary to allow his sandy farm to remain undisturbed in order to obtain a permanent blue-grass pasture to take the place of present poor crops and shifting sand. On the areas of pure sand many years would be required, but on most of the area where humus has accumulated from the natural vegetation of former years the time required might be commensurate with the returns.

In Figure 9, a summary of the succession of the principal associations of the natural prairie plants is given. Associations of weeds and cultivated grasses now present on the prairie as a result of the influence of civilization are omitted in this summary.

Composition of the Associations

In the preceding discussion of the associations emphasis is placed on the dominant species. Following is a list of the associations together with some of the more frequent secondary species found on less disturbed areas. This list made from small relic areas is not meant to be complete nor to represent absolutely the composition of the more extensive associations before they were disturbed by man. Certain limitations must be recognized. In the first place, the composition of an association is usually most representative near its center of distribution, and least representative near its boundaries where there is an overlapping of secondary species of adjacent associations. The centers of distribution of some of the associations have been entirely destroyed by cultivation, and only the boundaries remain for study. Under present conditions it is impossible in every case to list the secondary species with the association in which they were most common. In the second place,

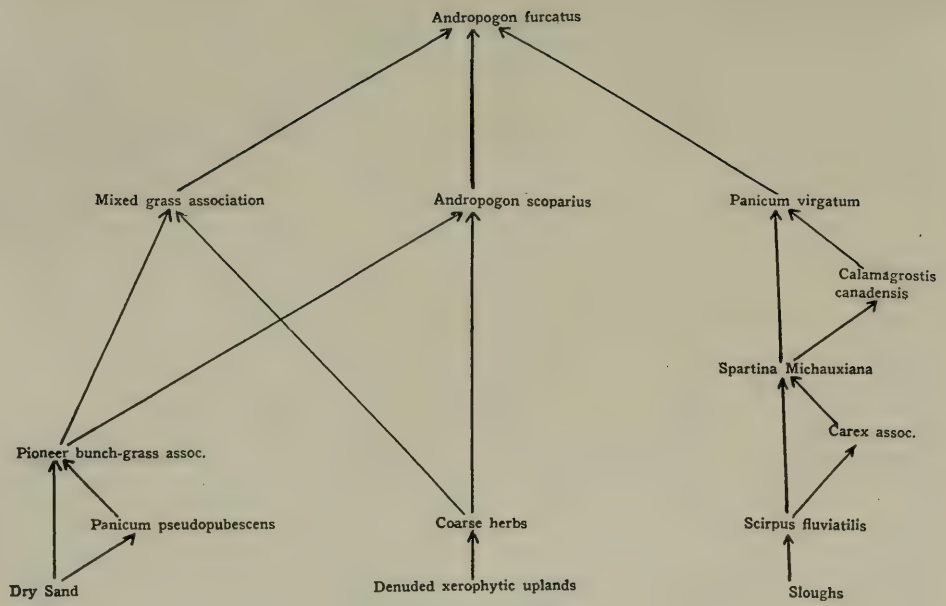


FIG. 9. A genetic classification of the prairie plant-associations in Illinois.

the habitat range of any species is more extensive when the biotic factors of competition are removed than when they are present. The numerous disturbances accompanying civilization usually eliminate the influence of biotic factors, at least in part, and admit not only a greater prominence of secondary species but also a wider edaphic range of all species than existed under natural conditions. Recently drained sloughs may be found in which Spartina still persists as the dominant plant, but the Spartina association in such cases may have as secondary species mostly plants characteristic of the Andropogon associations. It is obvious that a detailed account of associations under disturbed conditions is not only valuless but is confusing to the uninitiated. Secondary species of local prominence following drainage, grazing, or other disturbance are not included in the list below unless they were found to occur frequently in the same associations elsewhere. A more complete list of secondary species of any association may be obtained from the annotated list beginning on page 559 of this article.

The Scirpus fluviatilis Association.—*Scirpus fluviatilis, S. validus, Glyceria septentrionalis, Sparganium eurycarpum, Acorus Calamus, Sagittaria latifolia, Sium cicutaefolium, Pontederia cordata, Alisma Plantago-aquatica, Rumex verticillatus, Polygonum Muhlenbergii, P. hydropiperoides, P. amphibium, Eleocharis palustris, E. acicularis, Penthorum sedoides, Scutellaria galericulata, Ludvigia palustris, Mimulus ringens,* and *Ranunculus delphinifolius.*

Typha latifolia and sometimes *Phragmites communis* occur in this association when there has been some disturbance, such as tramping by grazing animals, pollution of the water, and dredging. With continued disturbance *Scirpus fluviatilis* disappears, and *Typha latifolia* dominates except for small colonies of *Phragmites communis* in some localities. The data obtained in this survey indicate that neither Typha nor Phragmites was abundant in the natural prairies of the state. *Scirpus validus* may form an association in deeper water beyond *Scirpus fluviatilis.* In the shade of trees *Sagittaria latifolia* usually replaces *Scirpus fluviatilis.*

Forest invasion of this association may occur. The principal invading species noted are *Cephalanthus occidentalis, Cornus stolonifera, Salix amygdaloides, S. nigra, S. cordata, S. discolor,* and *S. longifolia.*

The Carex Association.—This association needs considerable more attention than it received during this survey. *Carex vesicaria* appears to be the most important dominant species on flood-plains and in some of the morainal depressions, but other species were also noted as dominants, namely, *C. lanuginosa, C. stricta, C. Sartwellii,* and *C. vulpinoidea.* The secondary species are: *C. rostrata, C. lupulina, C. tribuloides, C. straminea, C. stipata, C. pennsylvanica, Scirpus atrovirens, Lobelia cardinalis, Steironema lanceolatum, Veronia fasciculata, V. altissima, Eupatorium perfoliatum, Asclepias incarnata, Stachys tenuifolia, Eleocharis palustris, E. obtusa, E. intermedia, Leersia oryzoides,* and *Phalaris*

arundinacea. These last two species may occur as local dominants between *Scirpus fluviatilis* and *Spartina Michauxiana,* and they may have been prominent in this position on the original prairies.

The Spartina Michauxiana Association.—Spartina Michauxiana, Elymus virginicus, Phalaris arundinacea, Leersia oryzoides, Glyceria nervata, Carex vulpinoidea, C. Bebbii, C. scoparia, C. lanuginosa, C. tribuloides, Eleocharis palustris, E. obtusa, E. intermedia, Juncus nodosus, J. Torreyi, J. tenuis, Cyperus strigosus, Stachys palustris, Lythrum alatum, Vernonia fasciculata, V. altissima, Steironema lanceolatum, Lycopus americanus, Aster paniculatus, Asclepias incarnata, Apocynum cannabinum var. *hypericifolium, Hypericum ellipticum, Iris versicolor, Lippia lanceolata, Senecio aureus,* and *S. Balsamitae.*

Forest invasion may occur in this association by the species noted aboye and also by *Populus deltoides,* less frequently by *P. grandidentata* or *P. tremuloides,* and *Cornus Amomum.*

The Calamagrostis canadensis Association.—Calamagrostis inexpansa, Aspidium Thelypteris, and *Onoclea sensibilis* were found to be more abundant in this association than elsewhere, but the remaining secondary species consist largely of an overlapping of the secondary species of the Spartina and Panicum associations. This condition agrees well with the fact that the Calamagrostis association is sometimes eliminated in the succession from Spartina to *Panicum virgatum.*

The Panicum virgatum Association.—Panicum virgatum, P. Lindheimeri, P. huachucae, P. tennesseense, Elymus virginicus, E. canadensis, Ranunculus fascicularis, R. septentrionalis, Baptisia leucantha, Anemone canadensis, Oxalis corniculata, Cicuta maculata, Steironema ciliatum, Physostegia virginiana, Veronica virginica, Liatris spicata, Solidago serotina, S. Riddellii, Cacalia tuberosa, Lathyrus palustris, Rudbeckia hirta, Stachys palustris, and *Gaura biennis.*

Forest invasion in this association on the flood-plain at Savanna was found occurring by three different methods: (1) by tree seedlings along the forest borders in the shade of overhanging branches which had eliminated the Panicum, (2) encroachment of Cornus and Crataegus by means of adventitious buds from the roots extending into the prairie, and (3) by scattered seedlings of *Fraxinus americana, Ulmus americana, U. fulva,* and *Populus deltoides* on the prairie. A recent fire in a small section of this prairie had destroyed most of the seedlings less than six feet in height.

The Andropogon furcatus Association.—Andropogon furcatus, Sorghastrum nutans, Panicum implicatum, P. praecocius, P. Scribnerianum, Sisyrinchium angustifolium, Comandra umbellata, Fragaria virginiana, Baptisia leucantha, Crotalaria sagittalis, Petalostemum purpureum, P. candidum, Desmodium illinoense, D. sessilifolium, Lespedeza capitata, Oxalis corniculata, Polygala sanguinea, P. verticillata, Euphorbia Preslii,

Hypericum punctatum, H. Drummondii, H. gentianoides, Viola papilionacea, V. pedatifida, V. sagittata, Phlox glaberrima, P. pilosa, Gaura biennis, Eryngium yuccifolium, Dodecatheon Meadia, Asclepias tuberosa, A. Sullivantii, Acerates floridana, Pycnanthemum flexuosum, Veronica virginica, Ruellia ciliosa, Vernonia illinoensis, V. missurica, Liatris squarrosa, L. spicata, Solidago nemoralis, S. graminifolia, Aster multiflorus, Silphium laciniatum, S. terebinthinaceum, Parthenium integrifolium, Heliopsis helianthoides, H. scabra, Rudbeckia hirta, R. triloba, Lepachys pinnata, Helianthus mollis, H. grosseserratus, Coreopsis palmata, Cacalia tuberosa, C. atriplicifolia, Lactuca canadensis, and *Prenanthes aspera.*

Forest invasion in this association in the absence of erosion is similar to that described for *Panicum virgatum* (p. 555). See plates LXXVI, LXXVII.

The Andropogon scoparius Association.—Andropogon scoparius, Sorghastrum nutans, Panicum Scribnerianum, Stipa spartea, Aristida oligantha, Sporobolus heterolepis, Danthonia spicata Comandra umbellata, Cassia Chamaecrista, Tephrosia virginiana, Lespedeza capitata, Euphorbia corollata, Eryngium yuccifolium, Asclepias verticillata, Scutellaria parvula, Pentstemon hirsutus, Ruellia ciliosa, Diodia teres, Kuhnia eupatoriodes, Liatris scariosa, Solidago nemoralis, S. rigida, S. graminifolia, Aster ericoides, A. depauperatus, A. multiflorus, Brauneria pallida, Helianthus mollis, and *Coreopsis palmata.*

Most of these plants are also found as secondary species on well-established *Andropogon scoparius* associations on sand such as the one shown in Plate LXXIV. There are also certain secondary species in this association remaining as relics from more xerophytic associations on sand: *Ambrosia, psilostachya, Callirhoë triangulata, Bouteloua hirsuta, Helianthus occidentalis, Aster sericeus, A. linariifolius, Cyperus filiculmis,* and *Koeleria cristata.* Many others occur during the earlier stages of the Andropogon associations on sand.

The secondary species of the mixed grass association on sand are practically the same as those listed for the *Andropogon scoparius* association.

The chief grasses in the pioneer bunch-grass and *Panicum pseudopubescens* associations on sand have already been listed. Further details regarding secondary species in these two associations may be obtained from the annotated list or, better, from Gleason's paper (9) on "The Vegetation of the Inland Sand Deposits of Illinois."

The association of coarse herbs on denuded and eroding soils is rather variable, depending upon the water content of the soil and the proximity of plants producing seeds. Several farm weeds and many of the coarse herbs listed for the two Andropogon associations may occur on these areas and in a great variety of different combinations.

The Relation of Prairie and Forest in Illinois.

The general relations of prairie and forest in the state have already been noted, and some of the invading forest species were listed with the secondary species of the prairie associations. Apparently any of the prairie associations may be invaded by forest under the present conditions. Four methods of invasion were noted: (1) forest invasion accompanying erosion by streams, (2) growth of tree seedlings along forest borders where the grasses are checked by the shade of overhanging branches, (3) the occasional establishment of isolated seedlings farther out on the prairie, and (4) the growth of adventitious branch-buds from the roots of certain trees and shrubs extending short distances into the prairie. See Plates LXXVI and LXXVII.

Many of the early writers claim that wherever the prairie was protected from annual fires the forest gradually encroached upon the grass-land. A quotation from Gerhard is interesting in this connection: "The first efforts to convert prairies into forest land were usually made on the part of the prairie adjoining the timber. A range of farms, which girded the entire prairie along its circumference having been established, three furrows were plowed all around the settlements in order to stop the burning of the prairie for the whole distance of the circuit in the neighborhood of these farms; whereupon the timber quickly grows up spontaneously on all the parts not burned, the groves and forests commencing a gradual encroachment on the adjoining prairies, so that one after another concentric circle springs up inside of the preceding, and thus the entire prairie is steadily narrowed from all sides until it is finally occupied, forming a vast region covered with timbers and farms."

Whether all of the prairie area of Illinois would have ultimately become forested under natural conditions is a matter of speculation. Within a few decades man has drained the sloughs and destroyed the prairie turf through cultivation with the result that trees may now be grown throughout the state. The development of natural drainage would no doubt in time have reduced the area of sloughs, destroyed a limited amount of prairie turf, and led to an increase of forested area. A basis of fact for this conjecture is found in the older glaciated regions with their older and better-developed drainage systems where forest occupies a greater proportion of the area than on the youthful topography of the more recently glaciated region. But forest invasion on the better-drained Andropogon prairies is exceedingly slow, and the existence of rather extensive Andropogon prairies on the older glaciated regions of the state shows that prairie vegetation may dominate for many thousands of years.

When the Deciduous Forest Formation comes into competition with the Prairie Formation, the *Andropogon furcatus* Association may be succeeded by several of the associations of the Deciduous Forest Formation. This is not to be interpreted as saying that the Prairie Formation is a transition between Plains Grass-land and Forest; neither is it to be

understood as one of the series of successions leading to the Deciduous Forest Climax. When the Prairie Formation is succeeded by Deciduous Forest associations, it is exactly the same phenomenon that occurs when the Deciduous Forest invades and succeeds the Northern Evergreen Forest Climax—the Abies-Picea-Betula Association. Only in this sense is the *Andropogon furcatus* Association a temporary climax.

We must therefore conclude that the Andropogon furcatus Association is the climax association of the true prairies.

Where the prairie grades off almost imperceptibly into Plains vegetation there is an intermediate region in which it is too dry for *Andropogon furcatus* and in which the *Andropogon scoparius* association is the climax association of the prairie. In this intermediate region in the hydrarch succession, *Andropogon furcatus* is succeeded by *Andropogon scoparius.*

Annotated List of Species

No attempt was made to make a complete list of all the prairie species in the state. The following list is added primarily to give a more complete record of the secondary species of the different associations, and an attempt is made to check them with reference to the associations in which they are most usually found. Introduced species, ruderals, and species found only on railway rights-of-way or greatly disturbed areas are listed usually without reference to associations. Some of the weeds and most of the species characteristic of forest borders and small forest openings, which do not extend very far out on the prairie, are omitted. This list, compiled from small relic areas and under the present disturbed conditions, is subject to the limitations previously discussed and can only approximate the distribution under natural conditions. Consequently reference is made only to the more prominent associations. These associations are referred to in the tabulation by initial letters as follows: S. f. a., *Scirpus fluviatilis* association, C. a., *Carex association*, S. M. a., *Spartina Michauxiana* association, C. c. a., *Calamagrostis canadensis* association, P. v. a., *Panicum virgatum* association, A. f. a., *Andropogon furcatus* association, A. s. a., *Andropogon scoparius* association, M. g. a., Mixed grass association on sand, P. b-g. a., Pioneer bunch-grass association on sand, P. p. a., *Panicum pseudopubescens* association. The nomenclature follows the Vienna Code, as given in the seventh edition of Gray's Manual.

	S. f. a.	C. a.	S. M. a.	C. c. a.	P. v. a.	A. f. a.	A. s. a.	M. g. a.	P. b-g. a.	P. p. a.
Polypodiaceae										
Aspidium Thelypteris		†	†	†						
Onoclea sensibilis			†	†						
Equisetaceae										
Equisetum arvense										
" hyemale										
" " var. intermedium								†	†	
Selaginellaceae										
Selaginella rupestris									†	†
" apus										
Typhaceae										
Typha latifolia	†	†								
Sparganiaceae										
Sparganium eurycarpum	†									
" angustifolium	†									
Najadaceae										
Potamogeton zosterifolius	†									
Alismaceae										
Sagittaria latifolia	†	†	†							
" graminea	†	†	†							
Alisma Plantago-aquatica	†	†								
Gramineae										
Andropogon scoparius						†	†	†		
" furcatus					†	†	†	†		
Sorghastrum nutans						†	†	†		
Digitaria sanguinalis										
Leptoloma cognatum							†	†	†	†
Paspalum Bushii									†	
" circulare						†				
Panicum capillare					†	†				
" dichotomiflorum										
" virgatum				†	†	†			†	
" perlongum									†	†
" Lindheimeri				†	†	†				
" huachucae				†	†	†				
" implicatum						†				
" tennesseense				†	†	†				
" praecocius						†				
" Scribnerianum						†	†			
" pseudopubescens							†	†	†	†
" Leibergii					†	†				
Echinochloa crusgalli										
Setaria viridis										
" glauca										
Cenchrus carolinianus									†	†
Zizania palustris	†									
Leersia oryzoides	†	†	†	†						
Phalarís arundinacea	†	†	†	†						

	S. f. a.	C. a.	S. M. a.	C. c. a.	P. v. a.	A. f. a.	A. s. a.	M. g. a.	P. b. g. a.	P. p. a.
Gramineae—*concluded*										
Stipa spartea							†	†	†	
Aristida oligantha						†	†			
" tuberculosa							†	†	†	†
Muhlenbergia mexicana						†				
Sporobolus cryptandrus									†	†
" heterolepis						†	†			
Agrostis alba			†	†	†	†				
" hyemalis					†	†				
Calamovilfa longifolia										
Calamagrostis canadensis			†	†	†					
" inexpansa				†						
Koeleria cristata							†	†	†	†
Danthonia spicata							†			
Spartina Michauxiana		†	†	†						
Bouteloua hirsuta							†	†	†	†
" curtipendula							†	†	†	
Phragmites communis	†									
Eragrostis megastachya										
" pectinacea							†	†	†	
" trichodes							†	†	†	
Dactylis glomerata										
Poa compressa				†	†	†				
" triflora					†					
" pratensis					†	†	†			
Glyceria nervata				†	†					
" septentrionalis	†	†	†	†						
Festuca elatior										
Bromus Kalmii										
Agropyron repens										
Hordeum jubatum			†	†	†					
Elymus virginicus		†	†	†	†					
" canadensis					†	†				
" glaucus					†					
Cyperaceae										
Cyperus aristatus	†	†	†							
" Schweinitzii							†	†	†	†
" strigosus			†	†	†					
" ovularis						†				
" filiculmis							†	†	†	†
Kyllinga pumila			†							
Eleocharis obtusa	†	†	†							
" palustris	†	†	†							
" acicularis	†	†	†							
" Wolfii	†	†	†							
" intermedia	†	†	†							
Stenophyllus capillaris								†	†	†
Scirpus validus	†									
" fluviatilis	†	†								

	S. f. a.	C. a.	S. M. a.	C. c. a.	P. v. a.	A. f. a.	A. s. a.	M. g. a.	P. b-g. a.	P. p. a.
Scirpus atrovirens		†	†	†						
" lineatus			†	†	†					
" pedicellatus	†	†	†							
Scleria triglomerata						†				
Carex scoparia			†	†	†					
" tribuloides	†	†	†	†						
" straminea	†	†	†							
" Bicknellii						†	†			
" festucacea						†	†			
" suberecta			†	†						
" Bebbii		†								
" Muhlenbergii							†	†	†	†
" gravida, var. laxifolia										
" vulpinoidea		†	†	†						
" stipata		†								
" crus-corvi	†	†	†							
" Sartwellii	†	†	†							
" stricta		†	†	†						
" " var. decora		†	†	†						
" Shortiana		†								
" pennsylvanica		†	†							
" grisea		†								
" filiformis		†	†							
" lanuginosa		†	†	†						
" squarrosa		†	†	†						
" Frankii		†								
" Schweinitzii		†	†							
" lupulina	†	†								
" vesicaria	†	†	†							
" rostrata	†	†	†							
Araceae										
Acorus Calamus	†	†								
Commelinaceae										
Tradescantia reflexa										
" virginiana										
Pontederiaceae										
Pontederia cordata	†									
Juncaceae										
Juncus tenuis			†	†	†	†				
" balticus, var. littoralis										
" nodosus			†							
" Torreyi			†	†	†					
" acuminatus			†	†						
Liliaceae										
Allium cernuum					†	†				
" canadense					†	†				
Lilium philadelphicum					†	†				
" canadense					†	†				
" superbum										

	S. f. a.	C. a.	S. M. a.	C. c. a.	P. v. a.	A. f. a.	A. s. a.	M. g. a.	P. b.g. a.	P. p. a.
Liliaceae—*concluded*										
Camassia esculenta					†	†				
Orchidaceae										
Spiranthes cernua						†				
Amaryllidaceae										
Hypoxis hirsuta					†	†				
Iridaceae										
Iris versicolor										
Sisyrinchium angustifolium					†	†				
Salicaceae										
Salix nigra	†	†	†	†						
" amygdaloides	†	†	†	†						
" longifolia	†	†	†	†						
" cordata										
" discolor										
" humilis					†	†				
" sericea			†	†	†					
Populus deltoides		†	†	†	†					
Urticaceae										
Parietaria pennsylvanica					†	†				
Santalaceae										
Comandra umbellata						†	†			
Polygonaceae										
Rumex crispus										
" altissimus					†					
" verticillatus	†	†	†							
Polygonum exsertum			†							
" tenue							†	†	†	†
" amphibium	†	†	†							
" Muhlenbergii	†	†	†							
" pennsylvanicum					†					
" acre	†	†	†							
" Persicaria										
" hydropiperoides	†	†	†	†						
Polygonella articulata										†
Chenopodiaceae										
Cycloloma atriplicifolium										†
Chenopodium album										
Amaranthaceae										
Amaranthus graecizans										
Froelichia floridana							†	†	†	†
Nyctaginaceae										
Oxybaphus nyctagineus										
Illecebraceae										
Anychia polygonoides									†	
Aizoaceae										
Mollugo verticillata										

	S. f. a.	C. a.	S. M. a.	C. c. a.	P. v. a.	A. f. a.	A. s. a.	M. g. a.	P. b. g. a.	P. p. a.
Caryophyllaceae										
Silene antirrhina									†	†
Saponaria officinalis										
Portulacaceae										
Talinum rugospermum										†
Ranunculaceae										
Ranunculus delphinifolius	†									
" fascicularis					†	†				
" septentrionalis					†	†				
Thalictrum dasycarpum										
Anemone cylindrica					†	†				
" canadensis				†	†	†				
Clematis Viorna						†				
Cruciferae										
Draba caroliniana									†	
Lesquerella argentea									†	
Lepidium virginicum										
Cardamine bulbosa		†	†							
Crassulaceae										
Penthorum sedoides	†	†	†							
Saxifragaceae										
Saxifraga pennsylvanica					†					
Heuchera hispida						†				
Rosaceae										
Fragaria virginiana						†				
Potentilla arguta						†				
" monspeliensis						†				
" canadensis					†	†				
Geum triflorum						†				
Rosa setigera										
" blanda						†				
" carolina		†	†							
" virginiana		†	†							
Leguminosae										
Cassia Chamaecrista						†	†	†	†	
Baptisia bracteata						†			†	†
" leucantha					†	†				
Crotalaria sagittalis						†				
Trifolium pratense										
Melilotus alba										
" officinalis										
Amorpha canescens							†	†	†	†
Petalostemum purpureum						†				
" candidum						†				
Tephrosia virginiana						†	†	†	†	
Astragalus canadensis										
Oxytropis Lamberti										
Desmodium illinoense						†				
" sessilifolium						†				

	S. f. a.	C. a.	S. M. a.	C. c. a.	P. v. a.	A. f. a.	A. s. a.	M. g. a.	P. b-g. a.	P. p. a.
Leguminosae—*concluded*										
Lespedeza capitata						†	†			
Vicia americana										
Lathyrus palustris			†	†	†					
Apios tuberosa					†	†				
Linaceae										
Linum sulcatum							†	†	†	
" medium					†	†				
Oxalidaceae										
Oxalis violacea						†				
" corniculata					†	†				
Polygalaceae										
Polygala polygama							†	†	†	
" sanguinea					†	†				
" verticillata					†	†				
" " var. ambigua					†	†				
Euphorbiaceae										
Croton glandulosus, var. septentrionalis										
Croton capitatus								†	†	
Crotonopsis linearis							†	†	†	†
Euphorbia Geyeri							†	†	†	†
" Preslii						†				
" maculata						†				
" humistrata						†				
" corollata						†	†	†	†	†
" dentata						†				
Callitrichaceae										
Callitriche autumnalis	†									
Malvaceae										
Callirhoë triangulata							†	†	†	
Hibiscus lasiocarpus										
Hypericaceae										
Hypericum punctatum					†	†				
" ellipticum			†	†	†					
" mutilum										
" Drummondii						†				
" gentianoides						†				
Cistaceae										
Helianthemum majus							†	†		
Lechea tenuifolia							†			
Violaceae										
Viola pedata								†	†	
" papilionacea					†	†				
" pedatifida					†	†				
" sagittata					†	†				
" lanceolata					†	†				
Cactaceae										
Opuntia Rafinesquii										†

	S. f. a.	C. a.	S. M. a.	C. c. a.	P. v. a.	A. f. a.	A. s. a.	M. g. a.	P. b.g. a.	P. p. a.
Opuntia fragilis									†	†
Lythraceae										
Lythrum alatum			†	†	†					
Onagraceae										
Ludvigia alternifolia			†	†						
" polycarpa		†								
" palustris		†	†							
Oenothera biennis										
" rhombipetala							†	†	†	†
" pratensis				†	†					
Gaura biennis					†	†	†			
Haloragidaceae										
Proserpinaca palustris	†	†								
Umbelliferae										
Eryngium yuccifolium						†	†			
Cicuta maculata			†	†	†	†				
Sium cicutaefolium	†	†	†							
Zizia aurea					†	†				
Polytaenia Nuttallii									†	
Pastinaca sativa										
Oxypolis rigidior										
Primulaceae										
Steironema ciliatum			†	†	†					
" lanceolatum	†	†	†	†						
" quadriflorum			†	†	†					
Dodecatheon Meadia					†	†				
Gentianaceae										
Sabatia angularis						†				
Gentiana puberula					†	†				
" Andrewsii					†	†				
" flavida					†	†				
Apocynaceae										
Apocynum cannabinum, var. hpericifolium			†	†	†					
Asclepiadaceae										
Asclepias tuberosa						†				
" incarnata		†	†	†						
" syriaca					†	†				
" Sullivantii						†				
" verticillata					†	†	†			
Acerates floridana					†	†				
" viridiflora						†			†	
Convolvulaceae										
Convolvulus sepium					†	†				
Polemoniaceae										
Phlox glaberrima					†	†				
" pilosa					†	†				
" bifida							†	†	†	

	S. f. a.	C. a.	S. M. a.	C. c. a.	P. v. a.	A. f. a.	A. s. a.	M. g. a.	P. b-g. a.	P. p. a.
Boraginaceae										
Lithospermum arvense						-				
" Gmelini							†	†	†	†
" canescens						†	†			
Verbenaceae										
Verbena angustifolia						†	†			
" hastata					†	†				
" stricta						†	†	†		
Lippia lanceolata		†	†							
Labiatae										
Teucrium canadense			†	†	†					
" occidentale										
Scutellaria lateriflora			†							
" parvula						†	†	†		
Prunella vulgaris										
Physostegia virginiana			†	†	†					
Stachys tenuifolia		†	†	†						
" palustris			†	†	†					
Monarda fistulosa						†				
" punctata							†	†	†	†
Hedeoma hispida								†	†	†
Satureja glabra										
Pycnanthemum flexuosum						†				
" virginianum						†				
" pilosum						†				
Lycopus americanus		†	†	†						
Solanaceae										
Physalis heterophylla						†	†	†		
" virginiana						†	†	†		
Scrophulariaceae										
Linaria canadensis									†	†
Pentstemon hirsutus						†	†			
Mimulus ringens	†	†	†							
Ilysanthes dubia										
Veronica virginica					†	†				
Gerardia paupercula				†	†					
Castilleja coccinea										
Pedicularis canadensis						†				
" lanceolata					†					
Acanthaceae										
Ruellia ciliosa						†	†			
Plantaginaceae										
Plantago Rugelii				†	†	†				
" aristata						†	†			
" virginica										
Rubiaceae										
Galium boreale										
" Claytoni			†	†	†					
" tinctorium			†	†	†	†				

	S. f. a.	C. a.	S. M. a.	C. c. a.	P. v. a.	A. f. a.	A. s. a.	M. g. a.	P. b-g. a.	P. p. a.
Rubiaceae—*concluded*										
Diodia teres							†	†		
Cephalanthus occidentalis	†	†	†							
Houstonia caerulea						†				
" lanceolata						†				
Lobeliaceae										
Lobelia cardinalis	†	†	†							
" spicata					†					
" inflata					†					
Compositae										
Vernonia fasciculata		†	†	†	†	†				
" altissima		†	†	†	†	†				
" illinoensis					†	†				
" missurica					†	†				
Eupatorium purpureum		†	†	†	†					
" serotinum					†	†	†			
" perfoliatum		†	†	†	†					
Kuhnia eupatorioides, var. corymbulosa						†	†	†	†	
Liatris squarrosa						†				
" cylindracea							†	†		
" scariosa						†	†	†		
" spicata			†	†	†	†				
Chrysopsis villosa							†	†	†	†
Solidago missouriensis						†	†	†		
" nemoralis						†	†	†	†	†
" canadensis										
" altissima										
" serotina			†	†	†					
" rigida						†	†	†		
" Riddellii			†	†	†					
" graminifolia						†	†			
Boltonia asteroides	†	†	†	†	†					
Aster sericeus							†	†	†	
" ericoides						†	†			
" depauperatus, var. parviceps							†			
" multiflorus						†	†	†		
" lateriflorus						†				
" Tradescanti			†	†	†					
" paniculatus			†	†	†					
" linariifolius						†	†	†	†	
" ptarmicoides										
Erigeron philadelphicus				†	†					
" annuus					†	†				
" ramosus					†	†	†	†	†	†
Antennaria plantaginifolia					†	†				
" neodioica					†	†				
Gnaphalium polycephalum						†	†	†		

	S. f. a.	C. a.	S. M. a.	C. c. a.	P. v. a.	A. f. a.	A. s. a.	M. g. a.	P. b. g. a.	P. p. a.
Compositae—*concluded*										
Silphium lacinatum			†	†	†	†				
" terebinthinaceum					†	†	†			
" integrifolium					†	†	†			
Parthenium integrifolium						†	†			
Ambrosia bidentata										
" artemisiifolia										
" psilostachya						†	†	†	†	†
Heliopsis helianthoides						†				
Rudbeckia triloba						†				
" hirta					†	†	†			
" subtomentosa					†	†				
Brauneria pallida						†	†	†		
Lepachys pinnata						†				
Helianthus petiolaris						†	†			
" scaberrimus						†	†	†	†	
" occidentalis, var. illinoensis						†	†	†	†	†
" mollis						†	†			
" grosseserratus					†	†				
" doronicoides										
Coreopsis palmata						†	†	†	†	
" tripteris										
Bidens frondosa			†	†	†	†				
" spp.										
Helenium autumnale										
Achillea Millefolium					†	†	†			
Anthemis Cotula										
Artemisia caudata							†	†	†	
Cacalia tuberosa			†	†	†	†				
" atriplicifolia						†				
Senecio aureus			†	†	†					
" Balsamitae			†	†	†	†				
Cirsium lanceolatum					†	†				
" discolor						†				
" pumilum										
Krigia amplexicaulis					†	†				
Taraxacum officinale										
" erythrospermum										
Lactuca scariola										
" canadensis					†	†	†	†		
" ludoviciana					†	†				
Prenanthes racemosa						†				
" aspera						†				

Non-technical Summary

The foregoing technical report is written, in the main, for trained botanists and agriculturists and needs no further summary. Since the prairie region of Illinois is the greatest natural asset of the state and, therefore, of considerable interest to the general public, it may not be amiss to end this report with a non-technical summary of its outstanding features.

The variations in the native fertility of the different soils of the state are a result mainly of the kinds of native plants that have grown upon these soils since the recession of the glaciers that formerly covered nearly the entire area of the state (map page 530). When the glaciers melted, the surface of the state was left covered with a deposit of clay, pulverized rock, and bowlders which the glaciers had picked up and carried southward from the Hudson and Labrador regions. The unequal deposition of this glacial drift left the state with a gently rolling topography. The depressions became shallow lakes, many of which were several square miles in area. Streams from the melting ice left rather large deposits of sand in some parts of the state. Thus the early postglacial soil, aside from these sand deposits, consisted of clay, pulverized rock, and bowlders, practically devoid of organic matter and of general uniformity throughout most of the state. The varying amounts of humus in these soils today are the results of the growth and decay of vegetation upon them during the postglacial period.

Botanists are reasonably certain that the first plants which grew upon the glacial drift were the same as those found growing today just south of the present glaciers in the north. The first zone of vegetation south of these glaciers is a tundra on which mosses, lichens, grasses, sedges, and low heath-like shrubs are the prominent plants; the second zone is the northern evergreen forest of spruce and fir on the uplands and bogs in many of the smaller lakes; the third zone is the deciduous hardwood forest with trees on the uplands and sedges in many of the shallow lakes.

As the glaciers receded from Illinois the tundra was replaced by the northern spruce-fir forest, and finally, the spruce-fir forest by the deciduous hardwood forest. This forest, however, did not cover all of the upland area of the state, a part of which was covered by tall grasses characteristic of the prairie, chiefly tall bluestem (*Andropogon furcatus*). Only about one third of the state became forested in contrast to the much greater proportion of forest to prairie in Indiana and Ohio. There is evidence that the prairie on the upland areas originated during a postglacial dry period when the prairie extended farther eastward than at present. The shallow postglacial lakes did not become forested but supported a luxuriant growth of herbaceous water plants which decayed, but slowly, beneath the surface water and gradually filled the lakes. In this way enormous sloughs arose and a deep deposit of humus accumulated. The

depth and area of these postglacial lakes are attested today by the depth and extent of the rich humus soils which accumulated in them. The deeper peat deposits in some parts of the state evidently had their origin in the postglacial bogs noted above.

As the postglacial lakes became filled and better drained through the decay of vegetation in them and partly by the vertical cutting of streams and the deposition of debris washed from the uplands, the pioneer water-plants died and were replaced by plants characteristic of the better-drained soils. The series of this succession of plants leading to the gradual filling of the sloughs may be seen today in areas little disturbed by man. At first the bulrushes are the most abundant and prominent plants accompanied by fewer individuals of many other water plants which are unable to become abundant in competition with the luxuriant growth of the bulrushes. The bulrushes, therefore, may be called the dominant plants at this stage of filling of the sloughs. A miniature bulrush slough is shown in Plate LIV. The bulrushes begin to die as the sloughs become drier through filling or drainage and are replaced by sedges which dominate during a second stage of deposition (Plate XLVIII). The sedges are followed by slough grass (*Spartina Michauxiana*. Plates XLIX, L). Sometimes the slough grass follows the bulrushes directly without an intervening sedge stage. At this stage the sloughs may become dry for a few months during summer, but are still too wet for cultivation. The slough grass is followed in order by blue joint-grass (*Calamagrostis canadensis*, Plate LI), and tall Panicum (*Panicum virgatum*) or by Panicum alone, which, in turn, is finally replaced by tall bluestem (Plates LXV–LXX). Tall bluestem remains as the dominant grass of the true prairie. The early settlers found most of the bluestem prairie dry enough for cultivation. All gradations in the filling of the sloughs were seen by the early settlers. Most of the prairie area on the older glaciated part of the state south of the latitude of Mattoon had become covered by tall bluestem, but a large part of the prairie region in the younger glaciated area north of this latitude was not dry enough for tall bluestem and abounded in numerous sloughs of bulrush and slough grass. These drained sloughs and prairies with their deep deposits of humus are now the most productive lands of the state.

Where the upland clay soils become covered with a prairie vegetation instead of a forest, the first abundant grass to appear upon them is short bluestem (*Andropogon scoparius*). This grass, in time, becomes crowded out and is replaced by the tall bluestem.

Some of the sand deposits of the state became forested, but a large part of them became covered with a prairie vegetation. The first plants that grew upon the dry moving sand-dunes were not plants of the prairie, but short grasses more characteristic of the plants found upon the sand hills of Kansas and Nebraska (Plate LXXI). These pioneer plants, in time, developed a carpet of vegetation sufficient to hold the sand against the force of the wind. Through their death and decay

humus was added to the sand, increasing both the stability and water-holding capacity of the sandy soils. This made conditions favorable for the growth of plants characteristic of the prairie. Short bluestem first became abundant and crowded out most of the pioneer plants (Plates LXXII, LXXIV). With further increase of humus, stability, and water content of the sandy soils tall bluestem came in and crowded out the short bluestem (Plate LXXV). This succession of grasses, leading ultimately to tall bluestem on the sand deposits, was not completed on all the sand areas of the state when the first settlers arrived. All gradations from the pioneer to the climax could be found.

Starting with the pioneer soil-conditions left by the melting glaciers, the accumulation of organic matter from vegetation and the work of erosion have been gradually changing the topography, water content, and composition of the soils of the state. The change in water content of the soil was the most potent factor underlying the changes in prairie vegetation discussed above. With a decrease in water content of the areas covered by sloughs and an increase in the water content of clay slopes and sand accompanying the increase in humus and stability of the soil, more and more of the prairie area became covered by tall bluestem. This grass was the most abundant and prominent prairie plant on all the well-drained and sufficiently moist prairie areas of the state. In all the successions of prairie plants accompanying the filling and draining of sloughs, the wearing down of clay slopes, and the stabilization of sandy soils, the ultimate vegetation of the prairie is dominated by tall bluestem. This means that tall bluestem is the climax grass of the prairies of Illinois. It will remain the dominant prairie plant under natural conditions unless the water content of the soil is again seriously changed. Where the turf is broken by eroding heads of ravines it may be succeeded by a forest. A glance at Dr. Brendel's map (page 526) shows that much of the forest area of the state has developed in this way and is generally distributed along all the creeks and rivers.

None of the pictures accompanying this report give an adequate conception of the former bluestem prairies. This grass forms a close sod and under good growing condition may reach the height of 10–12 feet. The early settlers say that they were unable to locate cattle on the prairie except by climbing some elevation and watching for the waving of the tall grass as the cattle walked through it. Its growth was sufficiently dense to crowd out most of the other prairie plants, among the most prominent of which were plants of the mint, bean, and sunflower families. On eroding clay slopes and along forest borders the yellow, blue, and white flowers of these coarse herbs became conspicuous in late summer and autumn. A glance at Plate L may give some impression of the rank growth of the prairie grasses.

The humus accumulated on our prairie soils does not supply food to our crop plants. Like all green plants they make their food chiefly out of water and carbon dioxide. In the manufacture of carbohydrates

and fats no other raw material is used, but in the manufacture of protein a supply of nitrates, sulphates, and a small amount of phosphates are also used. Decaying organic matter, however, does greatly increase the fertility of soils through its favorable effect on the water content of the soil, ease of root penetration, soil aeration, and soil temperature, checking the leaching of minerals, and being a source of carbohydrate supply for some of the nitrogen-fixing bacteria and fungi in the soil.

The decay of forest vegetation also adds humus to the soil, but not so rapidly nor in as great amounts as is added by the decay of prairie plants. The glacial drift that has been forested a considerable part of the time since the recession of the glaciers has much less humus accumulated in it than is found on the drift covered by a prairie vegetation. Soil surveys conducted by the Illinois Experiment Station show that the forested soils have only from 25–50 per cent. as much organic matter in them as is found in the adjoining prairie soils. This is a result of the fact that most of the forest vegetation accumulates and mostly decays on the surface of the soil, while the numerous roots and root-stocks of the prairie vegetation accumulate and decay more slowly beneath the surface of the soil. This difference, of course, does not apply to flood-plain forests, where deposition during overflows is an important factor in soil fertility, nor to the occasional small forest areas that have developed from swamps in which the slowly decaying organic matter accumulates under water during the greater part of the year. The greater amount of humus accumulated in the prairie soils increases their fertility over that of the forest soils by increasing the check on the leaching of minerals, such as calcium, and by increasing the other favorable effects of humus noted above. This explains why farms formerly forested decrease in yield from year to year more rapidly than farms on adjacent prairie soils, both of which have had the same history except for the different kinds of native plants that have grown upon them. Where erosion follows deforestation the cleared lands become unprofitable for cultivation within a few years. Such areas should be kept in permanent forests.

It is evident, therefore, that the variations in native fertility of the different soils of the state are a result, mainly, of the kinds of native plants that have grown upon them and the conditions under which these plants grew since glacial times. Prairie and forest, alike, developed on glacial till. Prairie vegetation has added more humus and brought about a bigger change in the surface soil than forest. Their subsoils are alike. It is obvious, therefore, that the cause of the original prairies or forests in Illinois is not to be found in the different compositions of the soils of today. Aside from climatic conditions, the water content of the soil and not the kind of soil has been the most important factor in determining what kind of native plants grew upon any given area of the state. Under the present conditions of drainage, whenever the prairie turf is broken by erosion or other means a forest vegetation may

develop, but this fact has no bearing upon the explanations of causes of the original prairies and forests of the state.

The progress of civilization during the last century has not only destroyed nearly all of the native prairies of the state but, likewise, some of the conditions that gave rise to them. Grazing, drainage, cultivation, and stream pollution have all been destructive to the native prairie flora. Cultivation has destroyed the prairie plants except along fences between the farms, while grazing has destroyed even these last remnants not reached by the plow. Intensive grazing accompanied by the introduction of blue grass and red top destroyed practically all of the native prairie plants on the farms not cultivated. The bluestem prairies became blue-grass pastures, and where drainage accompanied grazing the native plants of the sloughs were also replaced by blue grass. In areas too wet for blue grass, red top became abundant, while in still wetter areas sedges and rushes prevailed. The bulrushes were mostly killed by the tramping of cattle, and cattails became abundant in the undrained sloughs. Grazing on the sand prairies destroyed the bluestem, and blue grass became abundant, giving rise to blue-grass pastures on sand. But where the sand areas were still too dry for the bluestems, grazing has increased the number of blowouts in the sparser vegetation of plains grasses. Some of the bluestem prairies on sand were cultivated instead of pastured. This has led (1) to the destruction of much of the humus accumulated for centuries by the decay of the native grasses, and (2) to the exposure of loose sand to wind action through the destruction of the prairie turf. As a result, blowouts and sand dunes become increasingly abundant, and the farms must shortly be abandoned. Carefully conducted experiments would undoubtedly result in the discovery of more profitable methods of dealing with these sand areas.

The changes brought about by drainage are somewhat too complicated to be discussed in detail in this summary. Artificial drainage has lowered the water-table several feet and drained most of the sloughs. This has led to all degrees of destruction of the natural grasses of the sloughs and made conditions favorable for the migration into them of plants characteristic of better-drained soils. Artificial drainage led to a sudden disturbance of the balance that obtained under natural conditions, and plants that reproduce most readily had a chance to become prominent. As a result, many plants not prominent on the natural prairies became temporarily abundant on the newly drained areas. This condition is well represented on the railway rights-of-way today. Artificial drainage is also favorable to the development of forests on the wet prairies.

The effect of the pollution of streams and prairie ponds received little attention in this survey. It appears to have been destructive to bulrushes and favorable to the growth of cattails. Its chief economic effect is to be found in the destruction of algae, the main source of the food of fishes.

This summary would not be complete without a word on the causes of the prairie. No other question of the prairie has been discussed so frequently or widely, and the answers to the question are as widely variable as their authors. This is a result, largely, of the various authors emphasizing local factors which would not apply to the prairies as a whole, or emphasizing only one of several factors which operating together may explain the prairies, but when considered separately fall far short of an adequate explanation. For instance, prairie fires, grazing, and the character of the soil are factors that may affect the local distribution of prairie and forest at their borders, but become insignificant in any attempt to explain the prairies as a whole. In some cases they have been reported as favorable to forest, in others as favorable to prairie. As a matter of fact, prairie fires and grazing are an effect rather than a cause of the prairies. As shown above, this may be true also of the prairie soils in so far as they differ from forest soils. On the other hand, temperature, wind, humidity, rainfall, and topography were all important factors in causing the treelessness of the prairies, but no one of these five factors considered alone will explain the prairies.

Omitting topography for the moment, it is possible to analyze the effect of the remaining four factors in terms of only two factors. Temperature, wind, and humidity all affect the rate of evaporation of water, and it is in this way that they operate in affecting the development of forest and prairie. They may be dealt with as one factor, namely, evaporation. We have to consider, therefore, only the factors, evaporation and rainfall. Both rainfall and evaporation are measured in inches per year by the Weather Bureaus. The amount of evaporation is obtained by exposing standard open vessels of water and keeping the record of water loss each day. At the end of the year this may be calculated to terms of inches of water lost by evaporation.

If the number of inches of annual rainfall (precipitation in general) is divided by the number of inches of annual evaporation, these two factors may be expressed as a single factor, namely, the per cent. or ratio of rainfall to evaporation. When the rainfall-evaporation ratios obtained at various places in the United States are plotted on a map, we are able to determine the combined effects of the four climatic factors—temperature, wind, humidity, and rainfall—upon the distribution of the natural vegetation. (See map on page 524.) The region of the United States in which the ratio of rainfall to evaporation is between 60 and 80 per cent. coincides very closely with the prairie region. In general, where the ratio is less than 60 per cent. plains or deserts result; where it is more than 80 per cent. forests are found. Since the annual distribution of rainfall is also important, these figures are not absolute for all localities. Hence, the chief cause of the prairie lies in the combined action of the four climatic factors named above through their effect upon the water relations of the plants concerned.

Topography may effect the distribution of prairies through its effect on some one or more of the climatic factors, as in the exposure

or protection of slopes from prevailing winds or the direct rays of the sun. In Illinois, topography was an important factor in the origin of prairies that developed from postglacial lakes through its effect on the water content of the soil. Prairies also developed on some of the well-drained upland soil. Forests were more common on the higher moraines, flood-plains, and river bluffs.

To-sum up, climatic factors are of primary importance in determining the general boundaries of distribution of the prairies, while the ever changing topography and water content of the soil are important in determining where sloughs, prairies, or forests will develop within these boundaries. The effect of these soil factors is more prominent near the boundaries of the prairie region than near its center of distribution where we find prairies growing on the greatest range of soil conditions.

Where a prairie or swamp vegetation is once established still another factor becomes important in keeping out the forest even after the swamps have become well drained, namely, the ability of the tall grasses to outgrow and over-shade the seedlings of forest trees. In the case of the drier prairies the grasses with their well-established root system have a monopoly of the water supply in the soil, and may prevent the development of seedlings of forest trees.

Forest invasion of prairies however does occur. It may follow the destruction of the prairie turf by erosion or it may precede erosion. Forest invasion on non-eroded prairie soils in Illinois is more extensive on the older glaciated regions of the state than on the younger glaciated regions. On the Wisconsin glaciated region this invasion is most common on the slightly elevated prairies, but there are natural groves of forest on some of the non-eroded black prairie soils.

The Ohio State University,
Columbus, Ohio.

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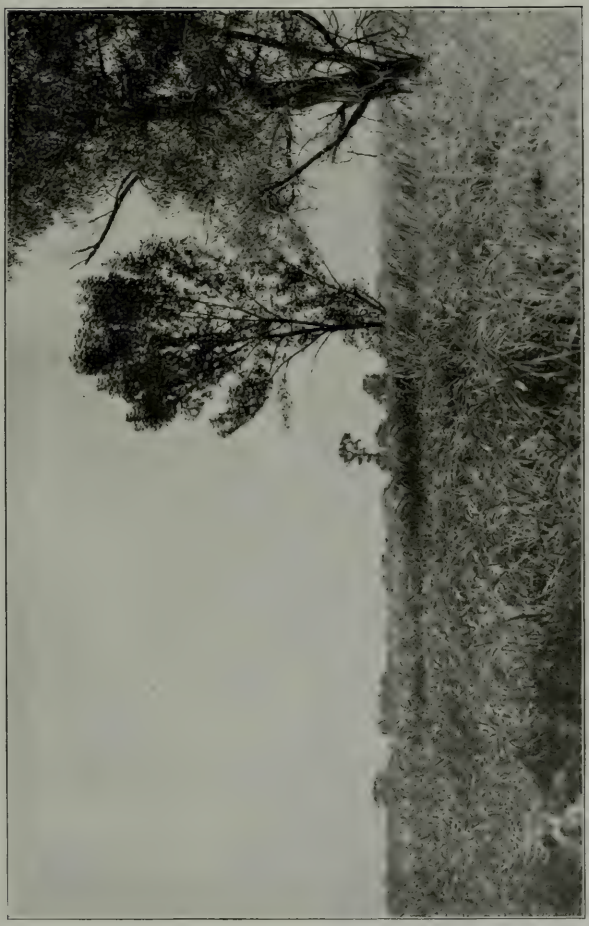
PLATE XLVIII



Carex vesicaria association in foreground, *Spartina Michauziana* association in background. Flood-plain, Savanna, Ill.

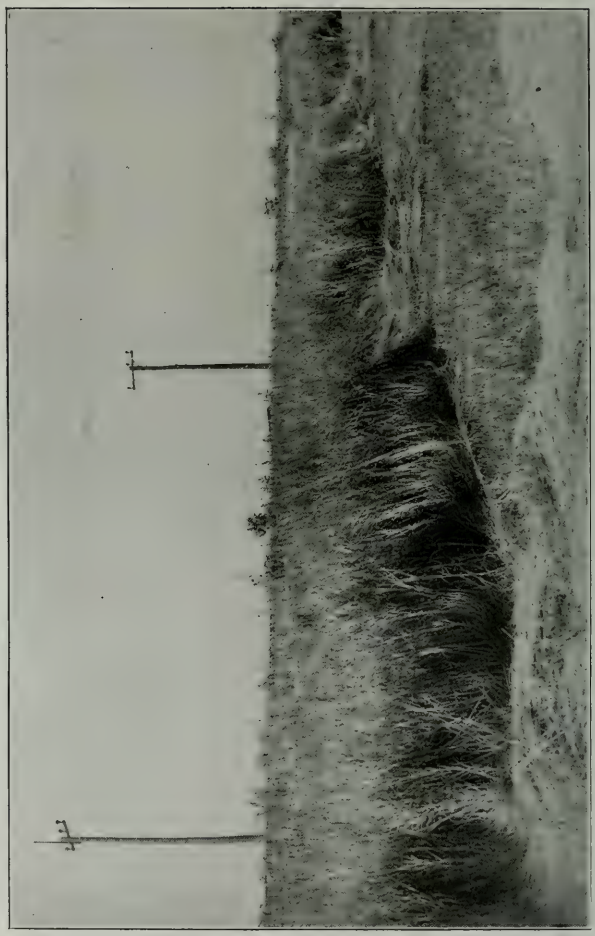
Plate XLIX

Same as Plate XLVIII, a few weeks later.

Plate L

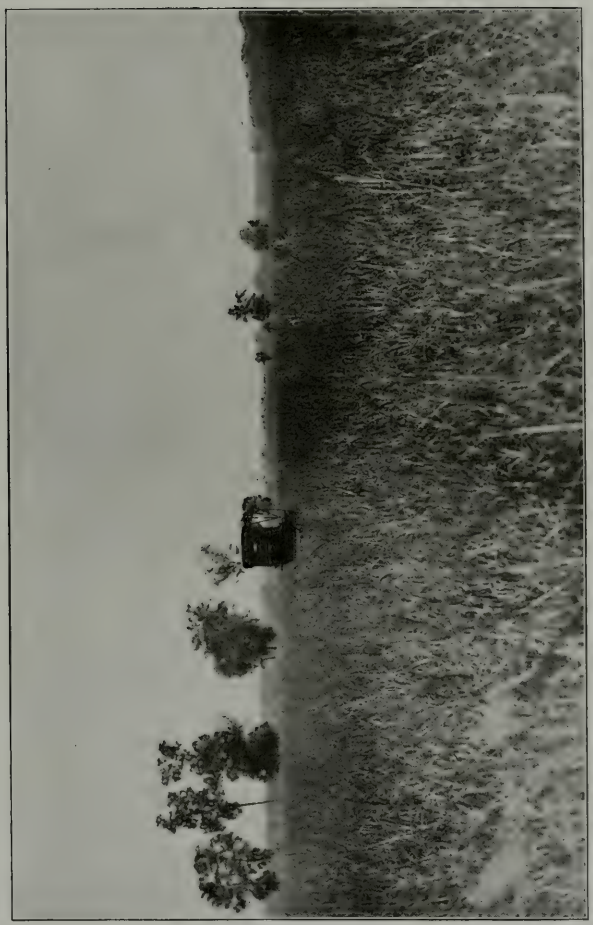
Spartina Michauxiana association. Flood-plain, Savanna, Ill.

PLATE LI



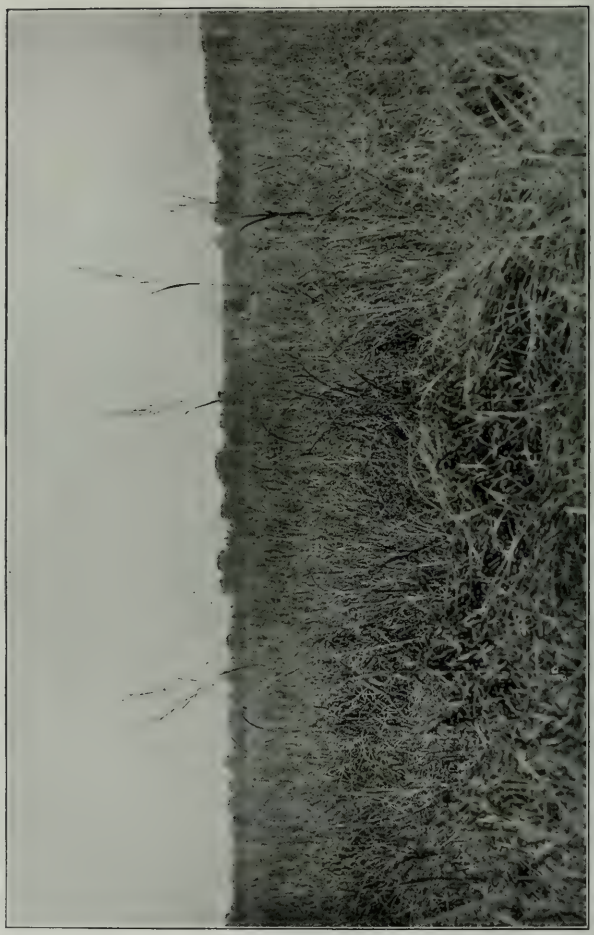
Calamagrostis canadensis association on the Chicago prairie. Luxuriant growth is indicated by proximity of windrows.

PLATE LII



Panicum virgatum association. Flood-plain, Savanna, Ill.

PLATE LIII

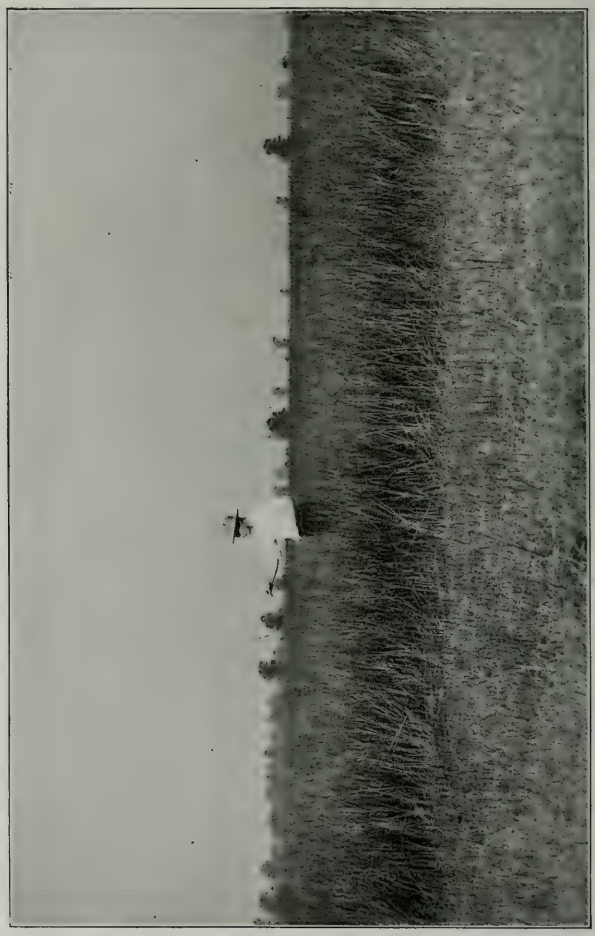


Andropogon furcatus in background. Some Spartina remaining in the narrow *Panicum virgatum* association in the foreground. Flood-plain, Savanna, Ill.

PLATE LIV

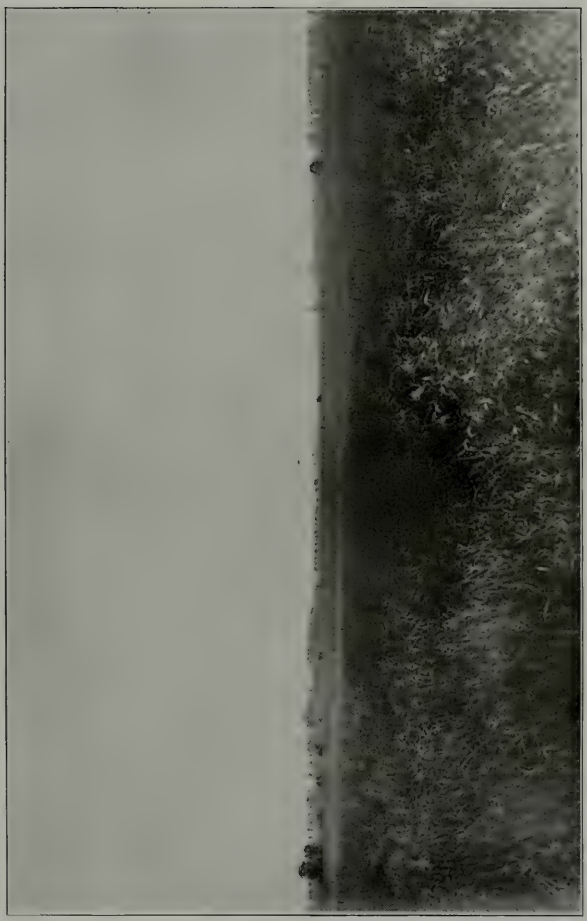
Scirpus fluviatilis association in a small prairie pond at Chicago Lawn. See diagram, Figure 3, page 537.

PLATE LV



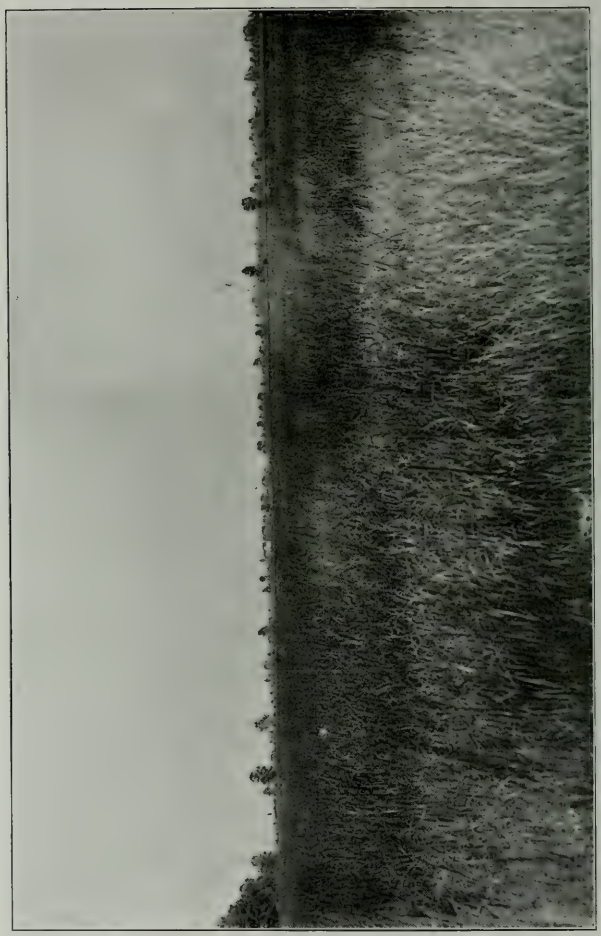
Spartina Michauziana association on the Chicago prairie at the stage of its second annual mowing.

PLATE LVI



General view of the Chicago prairie south of Oak Ridge. Trees on the Calumet beach in background.

PLATE LVII



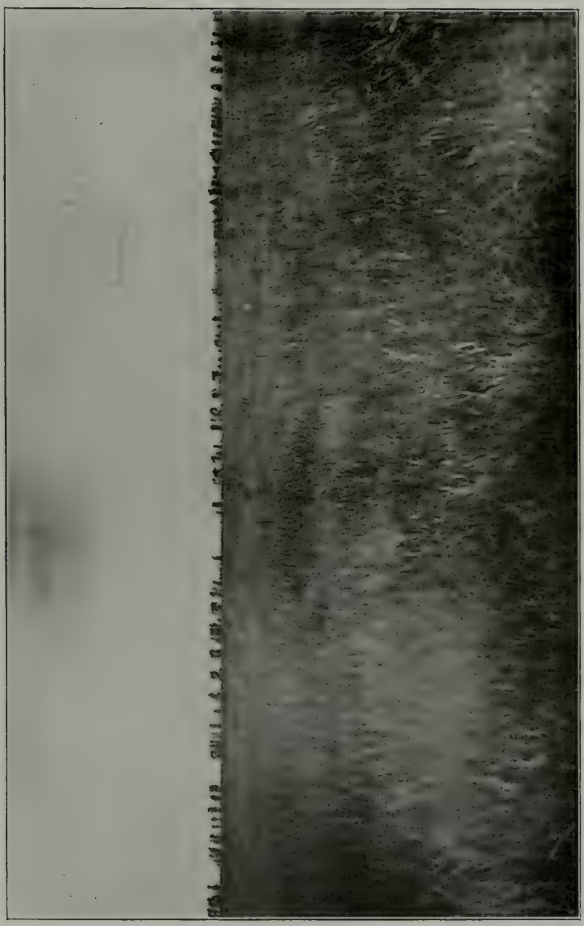
Panicum virgatum association. Chicago prairie. Trees along artificial drainage ditches.

Plate LVIII

Panicum virgatum association with Silphium and Liatris. Chicago prairie.

Andropogon furcatus coming into the *Panicum virgatum* association shown in Plate LVIII.

Plate LX

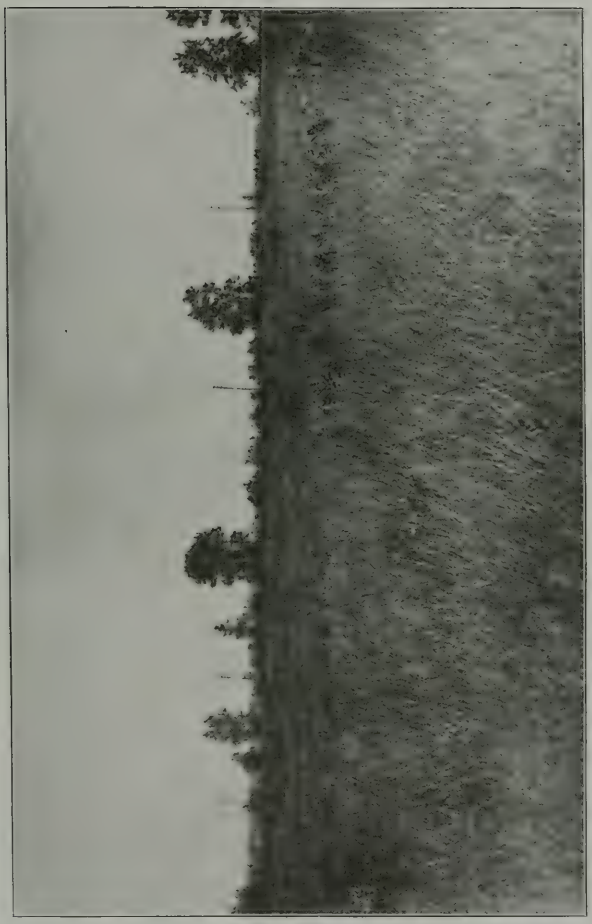


Agrostis alba (light color) in *Panicum virgatum* association. Chicago prairie.

PLATE LXI

Cacalia tuberosa in Spartina association. Chicago prairie.

PLATE LXII



Silphium laciniatum in Calamagrostis association. Chicago prairie.

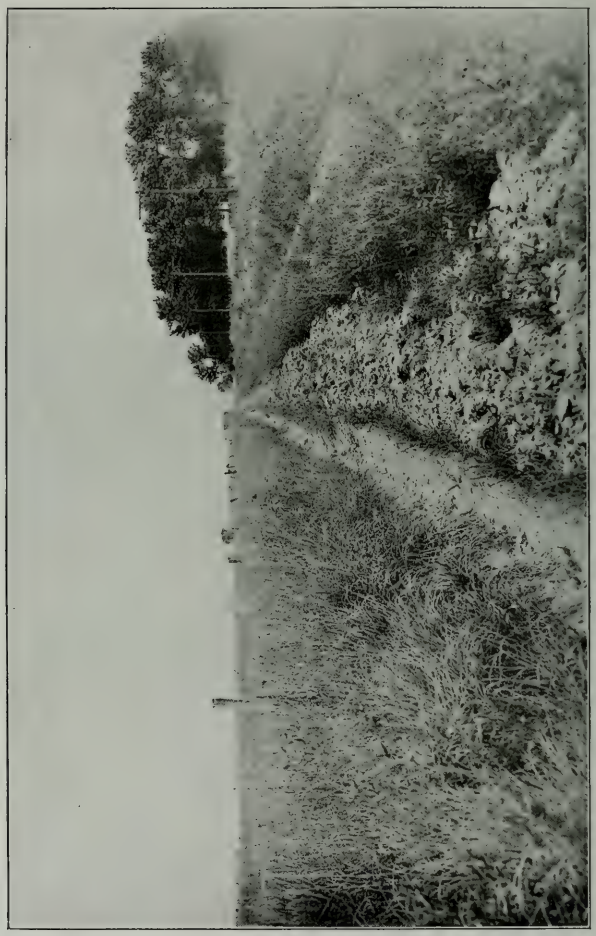
Plate LXIII

Silphium laciniatum in Spartina association. Chicago prairie.

Plate LXIV

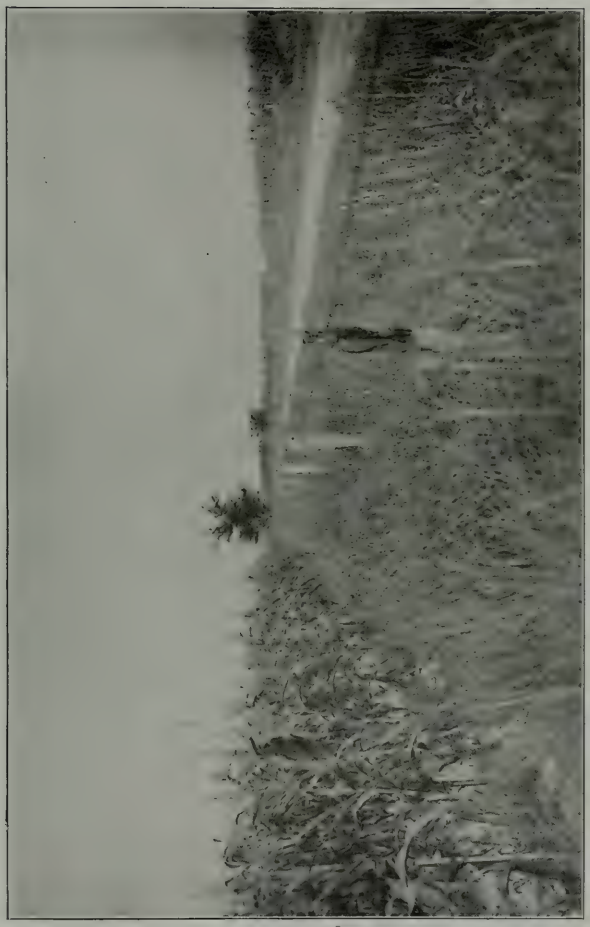
Silphium laciniatum and *S. terebinthinaceum* with Andropogon and Poa. Chicago prairie.

PLATE LXV



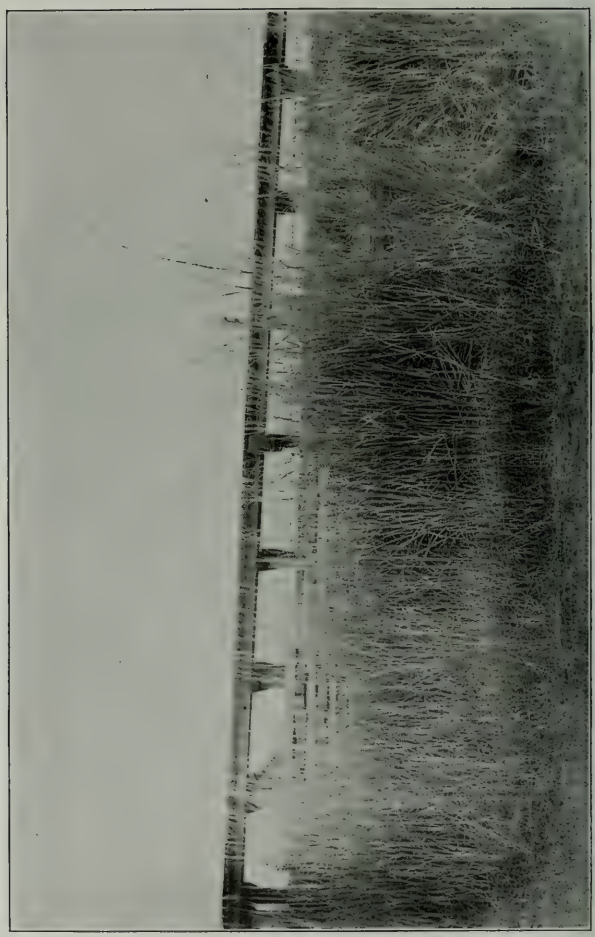
Andropogon furcatus along a roadway near Dietrich, Ill.

PLATE LXVI



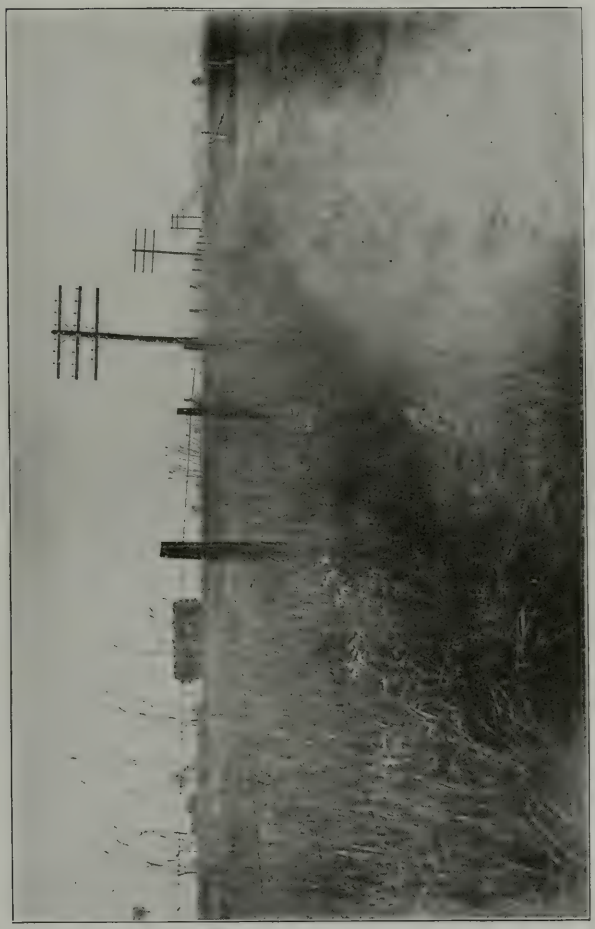
Andropogon furcatus along a roadway near Wheeler, Ill.

PLATE LXVII



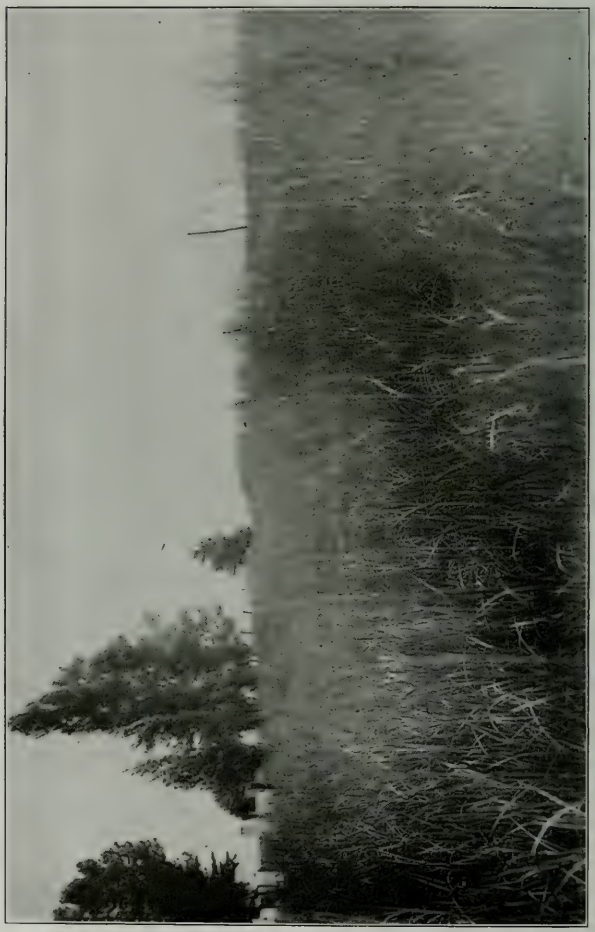
Andropogon furcatus near flowering stage. This strip of grass is about ten inches wide, and illustrates the dense growth and height of the tall bluestem. Effingham, Ill.

PLATE LXVIII



Andropogon furcatus more than seven feet tall on poor upland clay soil. Effingham, Ill.

Plate LXIX

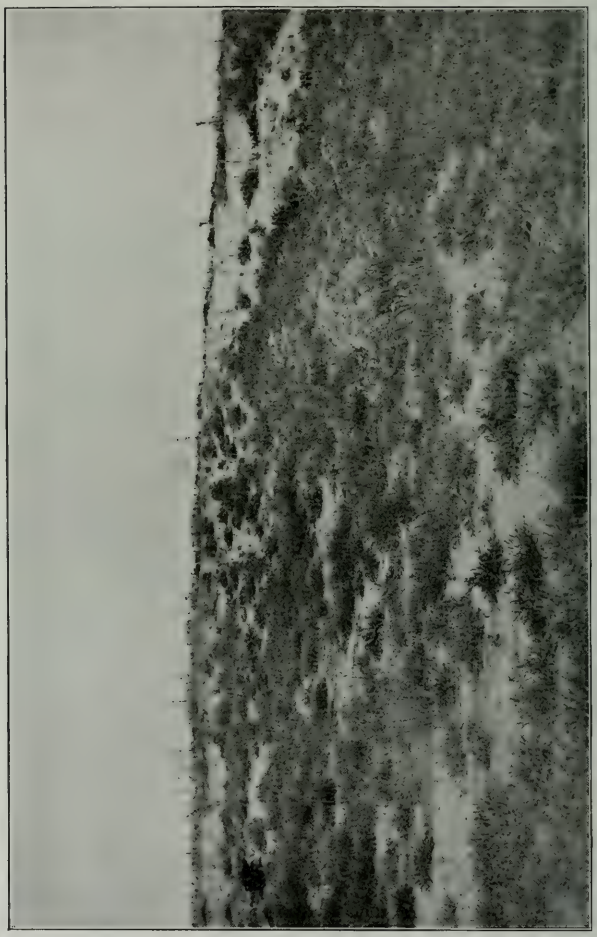


Andropogon furcatus on a railway right-of-way near Noble, Ill.

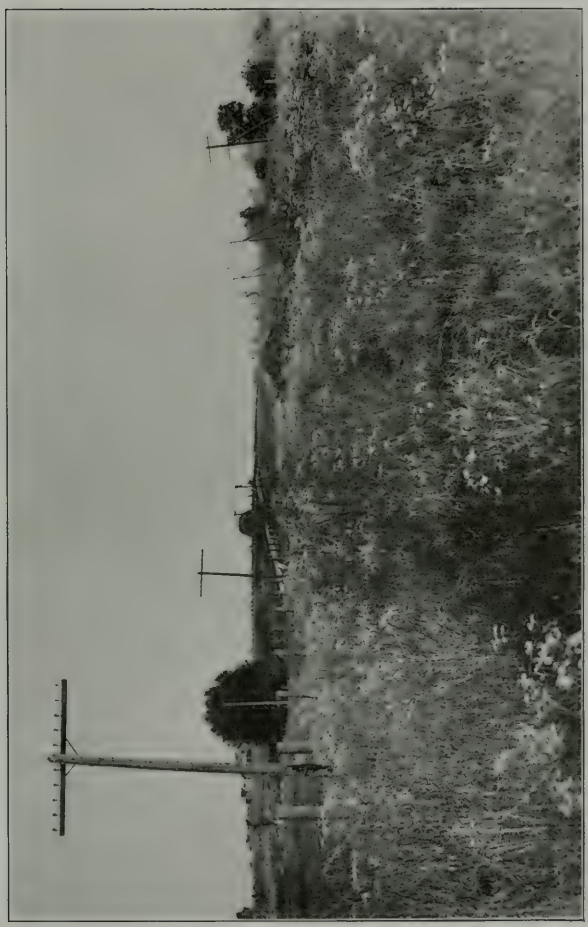
Plate LXX

Andropogon furcatus on a railway right-of-way formerly a forested area near Noble, Ill.

PLATE LXXI



Panicum pseudopubescens association on sand, near Savanna, Ill.

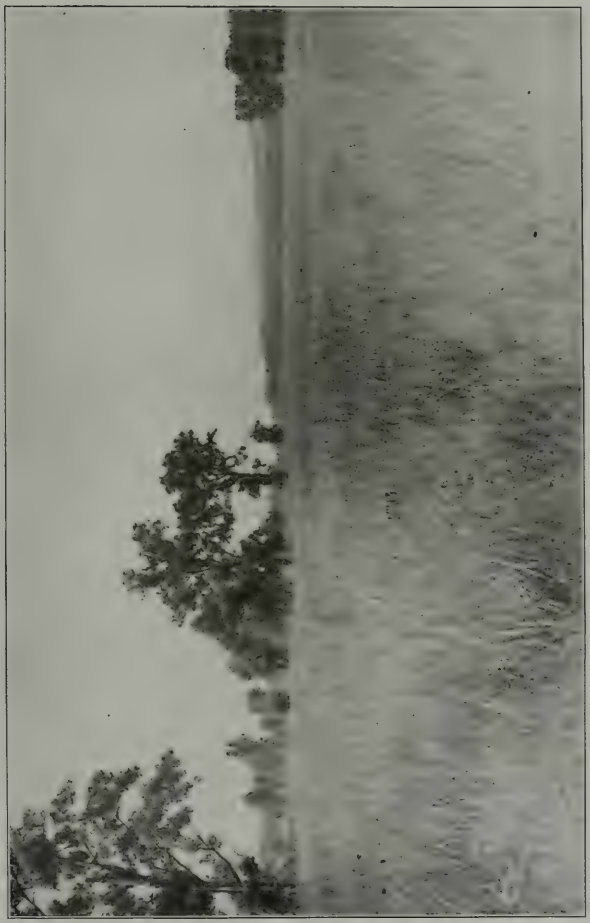


Andropogon scoparius association with *Euphorbia corollata* on sand along a railway right-of-way near Savanna, Ill.

PLATE LXXIII

Destruction of a bunch-grass association on sand by grazing, near Savanna, Ill. The tall clumps of grass remaining are *Andropogon scoparius*.

PLATE LXXIV

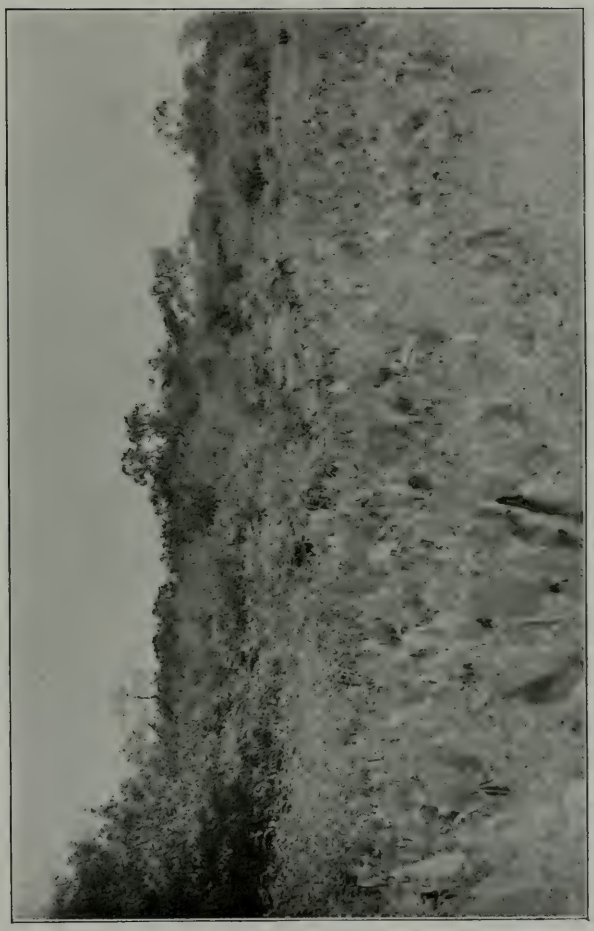


Andropogon scoparius association on a low sand hill south of Savanna, Ill.

PLATE LXXV

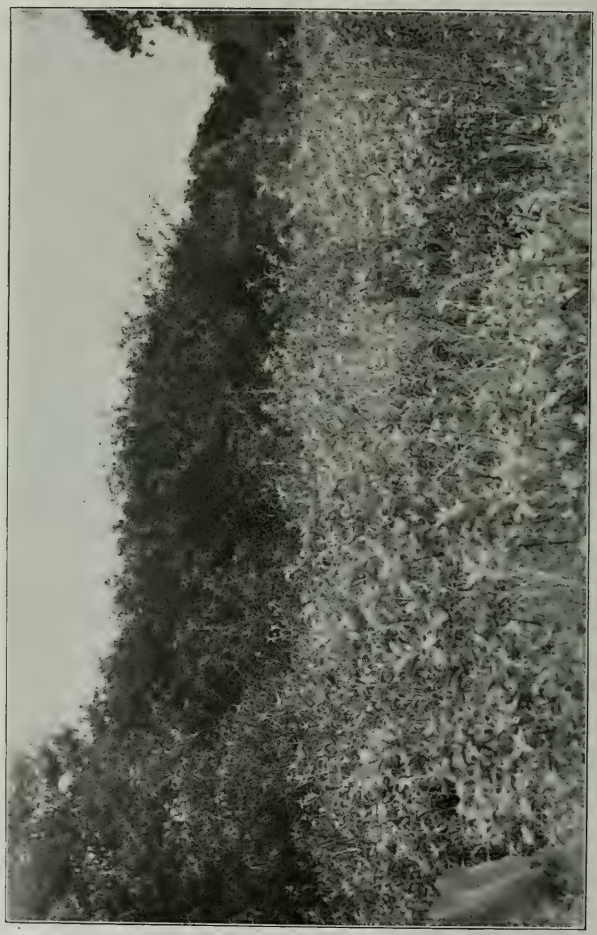
Andropogon furcatus association on a low sand hill south of Savanna, Ill. The grass at this stage is more than three feet high, and the secondary species occupy but a very small part of the association.

Plate LXXVI



Rhus glabra, *Pyrus coronaria*, and Crataegus encroaching upon a prairie near Riverside, Ill.

PLATE LXXVII



Prunus virginiana, *Pyrus coronaria*, and Crataegus encroaching upon a prairie near Riverside, Ill.

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STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
DIVISION OF THE
NATURAL HISTORY SURVEY
STEPHEN A. FORBES Chief

Vol. XIII. BULLETIN Article I.

THE NORTH AMERICAN SPECIES OF THE GENUS TIPHIA (HYMENOPTERA, ACULEATA) IN THE COLLECTION OF THE ILLINOIS STATE NATURAL HISTORY SURVEY

BY

J. R. MALLOCH

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
September, 1918